PB86-211869

Field Evaluation of Resource Recovery of Hazardous Wastes

Acurex Corp., Mountain View, CA

Prepared for

Environmental Protection Agency
Cincinnati, OH

Jun 86

U.S. Department of Commerce
National Technical Information Service
NTIS

PB86-211869

EPA/600/2-86/059
June 1986

FIELD EVALUATION OF RESOURCE RECOVERY OF HAZARDOUS WASTES

By

A. W. Wyss, C. Castaldini, and M. M. Murray
Acurex Corporation
Energy & Environmental Division
555 Clyde Avenue
P.O. Box 7555
Mountain View, California 94039

Contract 68-02-3176

EPA Project Officer: Robert E. Mournighan
Hazardous Waste Engineering Research Laboratory
Incineration Research Branch
26 West St. Clair
Cincinnati, Ohio 45268

HAZARDOUS WASTE ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/2-86/059	**2.**	**3. RECIPIENT'S ACCESSION NO.** PB86 211869/AS
4. TITLE AND SUBTITLE FIELD EVALUATION OF RESOURCE RECOVERY OF HAZARDOUS WASTES		**5. REPORT DATE** June 1986
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) A.W. Wyss, C. Castaldini, and M. M. Murray		**8. PERFORMING ORGANIZATION REPORT NO.** FR-85-157-EED
9. PERFORMING ORGANIZATION NAME AND ADDRESS Acurex Corporation 555 Clyde Avenue P.O. Box 7555 Mountain View, California 94039		**10. PROGRAM ELEMENT NO.**
		11. CONTRACT/GRANT NO. 68-02-3176
12. SPONSORING AGENCY NAME AND ADDRESS U.S.Environmental Protection Agency Hazardous Waste Engineering Research Laboratory 26 W. St. Clair St. Cincinnati, OH 45268		**13. TYPE OF REPORT AND PERIOD COVERED** Final Report
		14. SPONSORING AGENCY CODE EPA/600/12

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Incineration of mixed waste solvents in two process kilns was investigated during two 1-week field testing programs. The overall objective of this study was to evaluate the effectiveness of the two process kilns in destroying hazardous wastes and quantify stack gas emissions. During the test programs, samples of the hazardous wastes fired in the kilns were collected and analyzed for principal organic hazardous constituents POHCs, selected trace metals, and chlorides. Air emissions were sampled and analyzed for particulate matter (including trace metals); volatile and semivolatile POHCs found in the wastes and other products of incomplete combustion (PICs); and criteria pollutants including sulfur oxides, nitrogen oxides, carbon monoxide, and hydrochloric acid. Test results indicated that destruction and removal efficiencies (DREs) of POHCs at one site failed to meet the 99.99 percent level. POHC DREs at the second site were generally above this level. This disparity of results was attributed to difference in kiln operating temperature. Benzene, chlorobenzene, and carbon tetrachloride showed lowest DREs at both sites. Total PIC mass emissions accounted for 25 to 80 percent of the total measured POHC breakthrough. Trace element emissions, which were generally below 10 percent of the measured input rate, were dependent on the collection efficiency of the particulate control devices and waste firing rates.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Process Kilns Hazardous Waste	Hazardous Air Emissions RCRA Field Testing	Engineering Chemistry

18. DISTRIBUTION STATEMENT	**19. SECURITY CLASS** *(This Report)* Unclassified	**21. NO. OF PAGES** 192
	20. SECURITY CLASS *(This page)* Unclassified	**22. PRICE**

EPA Form 2220-1 (9-73)

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs, and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments and the need of both large and small businesses in handling their wastes responsibly and economically.

This report describes the results obtained from field testing and laboratory analyses of emission samples from two process kilns burning hazardous wastes. The primary objective of the program was to evaluate the effectiveness of the process kilns in destroying hazardous wastes and quantify other flue gas emissions. This information will be useful to regulatory officials during a permitting process and to members of the technical community who are seeking safe methods for hazardous waste disposal. For further information, please contact the Thermal Incineration Branch of the Hazardous Waste Engineering Research Laboratory.

David G. Stephan, Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

Incineration of mixed waste solvents in two process kilns was investigated during two 1-week field testing programs. The overall objective of this study was to evaluate the effectiveness of the two process kilns in destroying hazardous wastes and quantify stack gas emissions. During the test programs, samples of the hazardous wastes fired in the kilns were collected and analyzed for principal organic hazardous constituents (POHC's), selected trace metals, and chlorides. Air emissions were sampled and analyzed for particulate matter (including trace metals); volatile and semivolatile POHC's found in the wastes and other products of incomplete combustion (PIC's); and criteria pollutants including sulfur oxides, nitrogen oxides, carbon monoxide, and hydrochloric acid. Test results indicated that destruction and removal efficiencies (DRE's) of POHC's at one site failed to meet the 99.99 percent level. POHC DRE's at the second site were generally above this level. This disparity of results was attributed to difference in kiln operating temperature. Benzene, chlorobenzene, and carbon tetrachloride showed lowest DRE's at both sites. Total PIC mass emissions accounted for 25 to 80 percent of the total measured POHC breakthrough. Trace element emissions, which were generally below 10 percent of the measured input rate, were dependent on the collection efficiency of the particulate control devices and waste firing rates.

This report was submitted in fulfillment of EPA contract no. 68-02-3176 by the Acurex Corporation under the sponsorship of the U.S. Environmental Protection Agency. The report covers a period from October 1983 to August 1984, and work was completed as of July 1984.

CONTENTS

Section Page

Abstract iii
Foreword iv

1 Introduction 1

1.1 Background 1
1.2 Program Objectives 2

2 Kiln Description and Operation 3

2.1 Site I Description and Waste Fuels 3
2.2 Site II Description and Waste Fuels 6

3 Test Program and Kilns Operation 10

3.1 Kilns Operation 10
3.2 Fuel Characteristics 12

4 Emission Results 16

4.1 Criteria Gas Emissions 19
4.2 Particulate Emissions 23
4.3 Chloride Emissions 23

5 Organic Species Emissions and DRE's 30

5.1 Waste Fuel Organic Analysis 30
5.2 Site I Results 35

5.2.1 Emission Results 35
5.2.2 POHC DRE's 39
5.2.3 PIC Emissions 57

5.3 Site II Results 57

5.3.1 Emission Results 57
5.3.2 DRE Results 64
5.3.3 PIC Emissions 84

5.4 Relative Analysis of Site I and Site II DRE Results 84

6 Trace Element Emission Results 88

7 Conclusions 97

CONTENTS (Concluded)

Section Page

APPENDIX A -- SAMPLING PROTOCOL A-1

APPENDIX B -- ANALYTICAL PROTOCOL B-1

APPENDIX C -- KILN OPERATIONS AND SAMPLING SCHEDULES . . C-1

APPENDIX D -- ANALYTICAL RESULTS D-1

TABLES

Table		Page
1	Kilns Description	4
2	Nonhalogenated Compounds Contained in the Spent Solvents -- Site I	6
3	Specific Compounds Permitted for Incineration at Site II by the State Environmental Protection Agency	9
4	Summary of Kilns Operation	11
5	Waste Fuel Analysis -- Site I	13
6	Coal Analysis -- Site II	14
7	Waste Fuel Analysis -- Site II	15
8	Sampling and Analysis Protocol for Site I Rotary Kiln Clay Dryer	17
9	Sampling and Analysis Protocol for Site II Rotary Aggregate Kiln	18
10	Continuously Monitored Criteria Gaseous Emissions -- Site I	20
11	Continuously Monitored Criteria Gaseous Emissions -- Site II	21
12	Sulfur Balance -- Site II	22
13	Summary of Particulate Emissions Test Data -- Site I	24
14	Summary of Particulate Emissions Test Data -- Site II	25
15	Summary of Particulate Emissions -- Site I	26
16	Summary of Particulate Emissions -- Site II	26
17	Summary of Chloride Emissions -- Site I	27
18	Summary of Chloride Emissions -- Site II	27
19	Total Chloride Concentration in Scrubber Inlet and Outlet Streams -- Site II	28

TABLES (Continued)

Table		Page
20	Volatile Organics in the Feed -- Site I	31
21	Semivolatile Organics in the Feed -- Site I	32
22	Waste Solvent Volatile Organics -- Site II	33
23	Waste Solvent Semivolatile Organics -- Site II	34
24	Volatile Organic Emissions, Test 1 -- Site I	36
25	Volatile Organic Emissions, Test 2 -- Site I	37
26	Volatile Organic Emissions, Test 3 -- Site I	38
27	Semivolatile Organic Emissions -- Site I	40
28	Summary of 1,1,1-Trichloroethane DRE's -- Site I	41
29	Summary of Trichloroethane DRE's -- Site I	42
30	Summary of Benzene DRE's -- Site I	43
31	Summary of Tetrachloroethylene DRE's -- Site I	44
32	Summary of Toluene DRE's -- Site I	45
33	Summary of Chlorobenzene DRE's -- Site I	46
34	Summary of Methyl Ethyl Ketone (MEK) DRE's -- Site I . .	47
35	Summary of Freon 113 DRE's -- Site I	50
36	Summary of Ethylbenzene DRE's -- Site I	51
37	Summary of Acetone DRE's -- Site I	52
38	Summary of Styrene DRE's -- Site I	53
39	Summary of Xylene DRE's -- Site I	54
40	Summary of C_3-Alkylbenzene DRE's -- Site I	55
41	Summary of Volatile POHC DRE's -- Site I	56

TABLES (Continued)

Table		Page
42	Summary of DRE's for Semivolatile Organics -- Site I . .	58
43	Volatile PIC Emissions -- Site I	59
44	Volatile Organic Emissions, Test 1 -- Site II	60
45	Volatile Organic Emissions, Test 2 -- Site II	61
46	Volatile Organic Emissions, Test 3 -- Site II	62
47	Volatile Organic Emissions, Test 4 -- Site II	63
48	Summary of Dichloromethane DRE -- Site II	65
49	Summary of 1,2-Dichloroethane DRE -- Site II	66
50	Summary of 1,1,1-Trichloroethane DRE -- Site II	67
51	Summary of Carbon Tetrachloride DRE -- Site II	68
52	Summary of Trichloroethylene DRE -- Site II	69
53	Summary of Benzene DRE -- Site II	70
54	Summary of Tetrachloroethylene DRE -- Site II	71
55	Summary of Toluene DRE -- Site II	72
56	Summary of Chlorobenzene DRE -- Site II	73
57	Summary of 2-Butanone (MEK) DRE -- Site II	74
58	Summary of Freon 113 DRE -- Site II	77
59	Summary of Ethylbenzene DRE's -- Site II	78
60	Summary of Styrene DRE's -- Site II	79
61	Summary of Xylene DRE's -- Site II	80
62	Summary of C_3-Alkylbenzene DRE's -- Site II	81
63	Summary of 4-Methyl-2-Pentanone DRE -- Site II	82
64	POHC DRE Summary -- Site II	83

TABLES (Concluded)

Table		Page
65	Volatile PIC Emissions -- Site II	85
66	Site I Trace Metals Emissions -- Test I	89
67	Site I Trace Metals Emissions -- Test 2	90
68	Site I Trace Metals Emissions -- Test 3	91
69	Site II Trace Metals Emissions -- Test 1	92
70	Site II Trace Metals Emissions -- Test 2	93
71	Site I Trace Metals Emissions -- Test 3	94
72	Site I Trace Metals Emissions -- Test 4	95

SECTION 1

INTRODUCTION

This report presents emission results obtained from field measurements and laboratory analyses of samples from two industrial process rotary kilns fired with hazardous chemical wastes. The emissions measurement program was performed for the Incineration Research Branch of the EPA, contract no. 68-02-3176, Task 48, for the purpose of evaluating the thermal destruction efficiency of hazardous wastes in various combustion devices. Field testing under this contract was conducted in February and March 1984.

1.1 BACKGROUND

Thermal destruction of hazardous wastes by direct incineration or by cofiring in industrial processes and boilers can be economically and environmentally advantageous to landfill or chemical treatment. Direct incineration of hazardous wastes is regulated by Part 264 of the Resource Conservation and Recovery Act (RCRA) adopted in January 1981. These regulations require that principal organic hazardous constituents (POHC's)* present in significant concentrations in the waste must be disposed of with a destruction removal efficiency (DRE) exceeding 99.99 percent when calculated as follows:

$$DRE = (M_{feed} - M_{stack})/M_{feed} \times 100$$

where M_{feed} and M_{stack} are the mass flowrates of POHC's in the waste and in the flue gas, respectively. Thermal destruction of hazardous wastes in industrial processes and boilers is currently exempt from these regulations. Survey studies indicate that industrial process and boiler cofiring practices are widespread and likely to increase because of associated benefits. These benefits include displacement of conventional fuels and use of existing facilities for waste disposal in industries where incinerators are not available.

In June 1983, the states of North Carolina and Florida requested assistance from the U.S. EPA Region IV office to conduct emissions research testing at two industrial facilities: a shale/aggregate plant and an oil absorbent/"kitty litter" plant. At each of these facilities, liquid hazardous wastes are burned in rotary kilns as a fuel or fuel supplement. These activities are not subject to RCRA due to the beneficial fuel use exemption. However, there is concern regarding the possible threat to public health and the environment presented by the emissions from these facilities.

---

*POHC's are those compounds listed in Appendix VIII of the May 1980 RCRA amendments (40 CFR Part 261)

1.2 PROGRAM OBJECTIVES

The overall objective of this study was to evaluate the effectiveness of the two process kilns in destroying hazardous wastes and quantify stack gas emissions. The technical effort to accomplish the project objective consisted of conducting field sampling and analysis programs at both sites. During the test program, samples of the hazardous wastes fired in the kilns were collected along with a limited quantity of kiln operating data. Air emissions were sampled and analyzed for particulate matter (including trace metals); volatile, semivolatile and nonvolatile organic compounds; criteria pollutants including sulfur oxides, nitrogen oxides, carbon monoxide and hydrochloric acid.

The two kilns tested in this program are operated under substantially different conditions. Aside from use differences in their respective production processes, the kilns each have different geometrical dimensions, gas temperature profiles and operating schemes. Evaluation of the DRE for each of these facilities provided an opportunity for direct comparison of their thermal destruction characteristics.

SECTION 2

KILN DESCRIPTION AND OPERATION

Two rotary kilns were tested in this program. These are identified throughout this report as site I and site II. Table 1 summarizes the key design and operating characteristics of these two kilns.

Site I is a rotary kiln dryer which processes earth-type clays into products sold as cat litter and an impermeable liner for ponds. This is accomplished by reducing the moisture content of the clays from about 50 to 8 percent. Reprocessing of the 8 percent moisture clay to further reduce its moisture content to about 0.5 percent is also accomplished with the kiln dryer. The 0.5 percent moisture product is marketed as an oil and grease absorbent. The production capacity of the site I kiln is approximately 10 kg/s (40 tons/hr) requiring a heat input of about 11.0 MW (37.5 million Btu/hr). Kiln temperature and bulk gas residence times for capacity production of 8 percent moisture clay are estimated to be 590° to 650°C (1,100° to 1,200°F) and 2.5 sec, respectively.

The kiln at site II is an aggregate rotary kiln processing raw material in the form of shale into a lightweight aggregate. This is accomplished by liberating the carbon dioxide and promoting compositional changes in the raw material causing it to expand, thereby giving the aggregate its lightweight characteristic. A process temperature greater than about 1,040°C (1,900°F) is generally required to achieve this reaction. The kiln has an operating capacity of 2.3 to 2.5 kg/s (9 to 10 tons/hr) requiring a typical heat input ranging from 7.9 to 8.8 MW (27 to 30 million Btu/hr). Normal process temperatures in the kiln range from about 1,120° to 1,180°C (2,050° to 2,150°F). The kiln can be fired with either pulverized coal or liquid waste through two concentric burners. It has been estimated that the liquid waste will encounter temperatures in the range of 980° to 1,260°C (1,800° to 2,300°F) for 2.3 sec. Flame temperatures are estimated at 1,650°C (3,000°F).

The following sections describe the facility layout at each site and the composition of typical hazardous wastes incinerated in the kilns.

2.1 SITE I DESCRIPTION AND WASTE FUELS

Figure 1 illustrates a schematic of the site I kiln facility. Raw clay is fed into the exhaust end of the kiln. As the kiln rotates at 6-1/4 rpm and the clay moves through the kiln, water is driven off. The dried clay is

TABLE 1. KILNS DESCRIPTION

Parameter	Site I Rotary kiln dryer	Site II Aggregate kiln
Length, m (ft)	21.3 (70)	38.1 (125)
Diameter, m (ft)	2.1 (7)	2.7 (9)
Kiln rotation, rpm	6.25	1.1
Feed material	Earth-type clays	Shale
Process capacity, kg/s (tons/hr)	10 (40)	2.3 to 2.5 (9 to 10)
Feed material moisture, percent	50	NA
Product moisture, percent	8[a]	NA
Process temperature, °C (°F)	590 to 650 (1,100 to 1,200)	1,120 to 1,180 (2,050 to 2,150)
Estimated gas residence time, sec	2.5	2.3
Typical heat input at capacity, MW (million Btu/hr)	11.0 (37.5)	7.9 to 8.8 (27 to 30)
Fuel fired	Waste oils and waste solvents	Pulverized coal and liquid waste
Particulate control device	Fabric filter baghouse	Mechanical collector and wet scrubber

[a] Product can be reprocessed for 0.5 percent moisture

NA — Not available

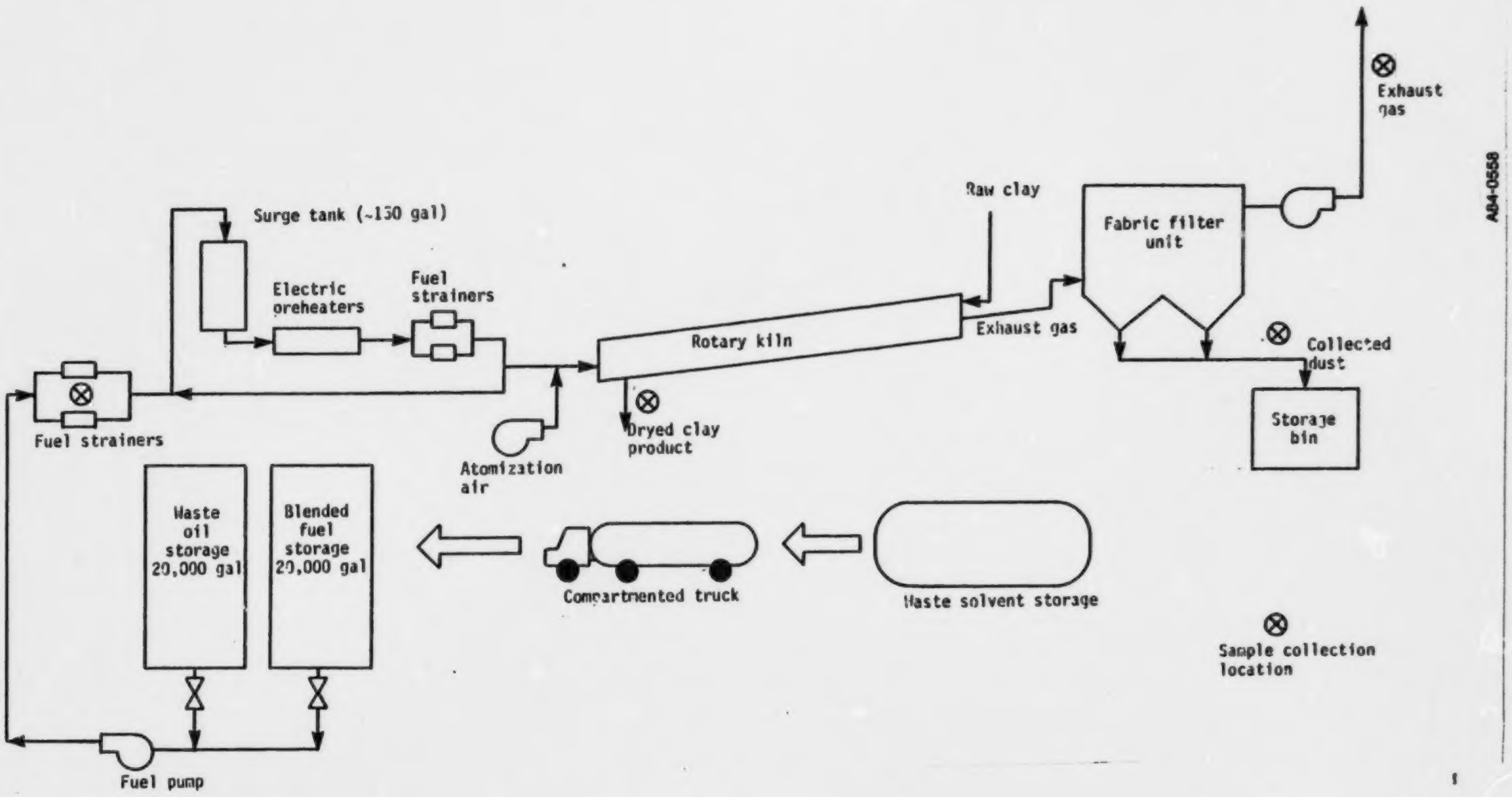

Surge tank (~130 gal)
Electric preheaters
Fuel strainers
Fuel strainers
Atomization air
Rotary kiln
Dryed clay product
Raw clay
Exhaust gas
Fabric filter unit
Exhaust gas
Collected dust
Storage bin
A04-0558
Waste oil storage 20,000 gal
Blended fuel storage 20,000 gal
Compartmented truck
Waste solvent storage
Sample collection location
Fuel pump

Figure 1. Process flow schematic and sample collection locations -- site I.

removed from the flame end of the kiln. The reintrained dust is collected by a fabric filter baghouse. The kiln is equipped with a minimal amount of process instrumentation.

The plant receives and stores liquid burnable hazardous wastes onsite for use as a fuel in the rotary kiln clay dryer. These wastes are blended with reclaimed oils or virgin oil before being fired into the kiln through one burner. The fuel, as fired, will contain a maximum of 20 percent liquid hazardous waste solvents. A blended fuel is desired for two reasons. First, blending the waste solvents with reclaimed oil produces a mixture with a flash point lower than the solvent. Thus, the mixture is safer to handle. In addition, a waste oil/solvent blend is easier to combust than straight waste oil. There are also favorable economics in using waste solvents as a supplemental fuel to the extent that they are available. Table 2 summarizes the typical composition of the waste solvents. As indicated, the waste solvents are a mixture of nonhalogenated hydrocarbons. Methyl ethyl ketone (MEK) and toluene are the only two identified RCRA Appendix VIII compounds in this typical mixture.

2.2 SITE II DESCRIPTION AND WASTE FUELS

Figure 2 illustrates a plant layout of the site II kiln. Raw shale is conveyed to the exhaust-end of the kiln and heated as it moves to the flame-end of the rotating kiln. The kiln rotates at a rate of 1.1 rpm. Pulverized coal and liquid wastes are injected through two concentric burners placed along the center axis of the kiln. The liquid wastes are atomized with air provided by a blower, and combustion air enters the kiln along with the pulverized coal. Additional air is pulled into the kiln through openings near the flame-end of the kiln by an ID fan. The kiln can be operated by burning only pulverized coal or liquid wastes or a combination of both coal

TABLE 2. NONHALOGENATED COMPOUNDS CONTAINED IN THE SPENT SOLVENTS -- SITE I[a]

Methyl ethyl ketone (MEK)[b]	Isopropanol
Ethyl alcohol	Toluene[b]
Mineral spirits	Acetone
Petroleum ether	Cyclohexane
Paint thinner	Isobutyl alcohol
JP-4	Xylene

[a] Composition not limited to components listed
[b] RCRA Appendix VIII listed hazardous organics

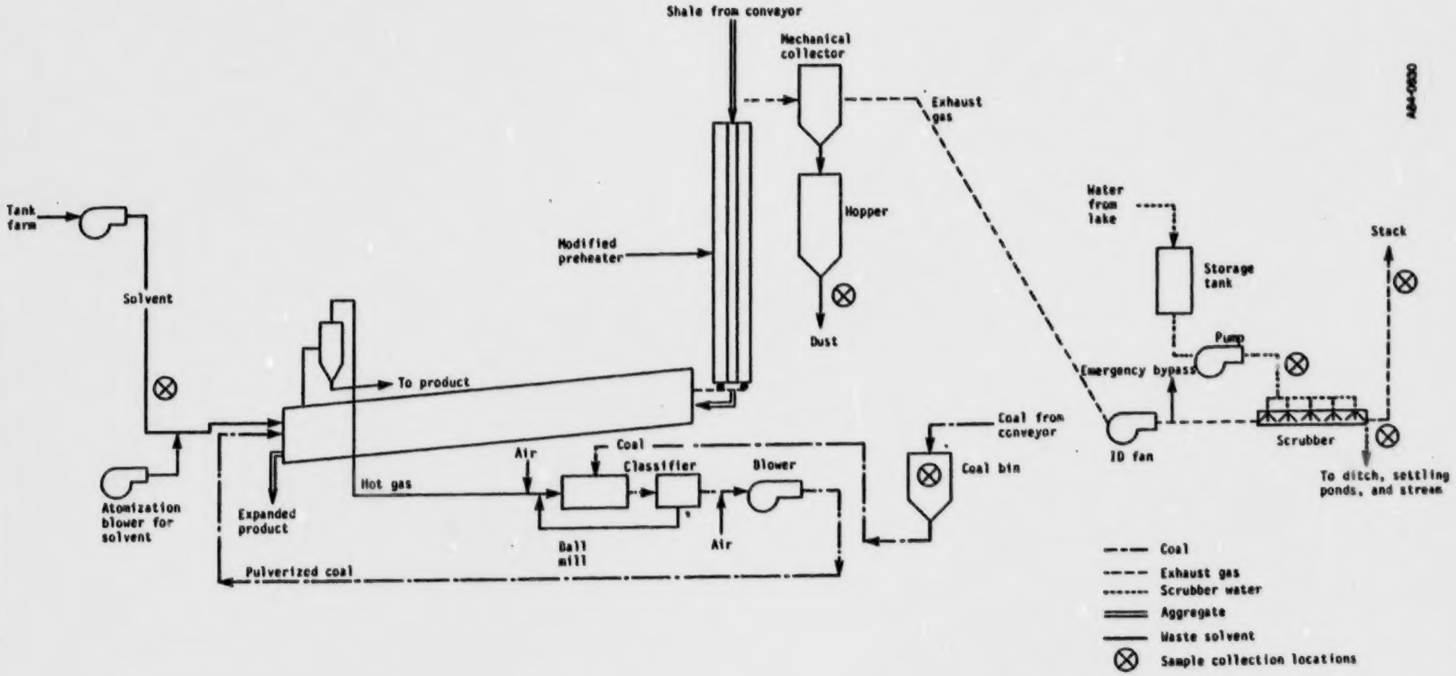

Shale from conveyor
Mechanical collector
Exhaust gas
A84-0830
Tank farm
Solvent
Modified preheater
Hopper
Dust
Water from lake
Storage tank
Stack
Pump
Emergency bypass
To product
Coal from conveyor
ID fan
Scrubber
Coal bin
To ditch, settling ponds, and stream
Coal
Air
Classifier
Blower
Hot gas
Atomization blower for solvent
Expanded product
Ball mill
Air
Pulverized coal
Coal
Exhaust gas
Scrubber water
Aggregate
Waste solvent
Sample collection locations

Figure 2. Process flow schematic and sample collection locations -- site II.

and liquid wastes. Fuel flow is adjusted by a controller that measures the temperature of the kiln wall, compares this value with a preset level, and adjusts the fuel flow accordingly. Other than this device, the kiln lacks process monitoring instrumentation. The maximum permitted liquid fuel firing rate is 372 ml/s (350 gph) with a nominal rate of 278 to 300 ml/s (265 to 290 gph). Other than this device, the kiln is equipped with minimal additional instrumentation. For example, it is not equipped with exhaust gas monitors.

Dust-laden gases from the aggregate kiln are passed through an air cleaning system that is vented through a stack. Emissions are controlled by a multicyclone unit (18 cyclones, each with a 30-cm (12-in.) body diameter) followed by a cross-flow gravity spray wet scrubber. The scrubber uses once-through scrubbing water obtained from a nearby surface water supply. Spent scrubber water is sent to a settling pond for clarification and then discharged to a local stream. A liquid flowrate of 6.3 to 9.5 l/s (100 to 150 gpm) is maintained through the spray scrubber system. Dust collected by the multicyclone unit is landfilled or sometimes reprocessed in the kiln.

The liquid burnable wastes received and burned by site II are a mixture of primarily nonhalogenated and some halogenated hydrocarbons in varying proportions. These materials are transported to the facility by truck and are combined with other shipments in a bulk storage facility. Each truckload of materials received at site II is tested prior to acceptance and subsequent incineration. The waste is analyzed for heat, chloride, moisture, and ash content. Every twelfth load is analyzed for PCB's. Once accepted, the wastes are mixed with other wastes to achieve a heat content of at least 25 MJ/l (90,000 Btu/gal). This is the minimum value necessary for the production of the lightweight aggregate. The waste fuels are also blended to a maximum chloride content of 2 percent, since this is the limit set in the applicable air pollution permit.

Typical waste materials which may be considered for use in the site II kiln include items from the following general categories:

- Natural or synthetic liquid flammable/ignitable organic compounds including dissolved resins and suspended solids and still bottoms from chemical recycling operations
- Flammable solids which can be melted or crushed
- Paint, ink, or dye residues or dirty wash solvents including organic and inorganic pigments and dissolved resins
- Petroleum products such as gasoline, mineral spirits, waste oil, or lubricants

Specific compounds that site II is permitted to burn are listed in Table 3. Materials that are not acceptable to be disposed of in the kiln include inorganic acids, organic cyanides, sulfides, lachramates, mercaptans, PCB's, insecticides, pesticides, herbicides, or radioactive materials. Spent

Table 3. SPECIFIC COMPOUNDS PERMITTED FOR INCINERATION AT SITE II BY THE STATE ENVIRONMENTAL PROTECTION AGENCY

Acetaldehyde[a]
Acetone
Acetonitrile[a]
Acrylic acid
Acrylonitrile[a]
Aniline
Benzene[a]
Benzidine[a]
N-Butyl alcohol
Carbon tetrachloride[a]
Creosote[a]
Cresols
Cresylic acid
Cumene
Cyclohexane
Cyclohexanone
Dimethylamine
Dipropylamine
Ethyl acetate
Ethyl acrylate
Ethyl ether
Ethyl methacrylate
Formaldehyde[a]
Furan
Furfural
Isobutyl alcohol
Isopropyl alcohol
Methanol
Methyl ethyl ketone[a]
Methyl isobutyl ketone
Methylene chloride[a]
Naphthalene[a]
2-Nitropropane
1,3-Pentadiene
Phenol[a]
N-Propylamine
Pyridine[a]
Resorcinol
Tetrachloroethylene[a]
Tetrahydrofuran
1,1,1 Trichloroethane[a]
Trichloroethylene[a]
Toluene[a]
Toluenediamine[a]
Xylene

[a] RCRA Appendix VIII hazardous compounds

solutions or sludges from electroplating, metal heat treating, wood treating, leather tanning and finishing, and metal treating are also not handled by this facility.

SECTION 3

TEST PROGRAM AND KILNS OPERATION

The primary objective of the test program at both test sites was to measure the kiln's destruction and removal efficiency (DRE) of hazardous organic compounds in the waste fuels under typical kiln operating conditions. Waste fuels at both sites were spiked with a known quantity of 1,1,2-trichloro-2,2,1-trifluoroethane (Freon 113) to permit a direct comparison of DRE results between the two test sites and to investigate the feasibility of using Freon 113 as a surrogate for DRE measurements of other major POHC's in the waste fuels. Three tests were performed at site I over a 3-day period with the kiln firing a mixture of waste oil and spent hydrocarbon solvents. At site II, four tests were performed over a 4-day period. Two tests were performed with the kiln burning a combination of liquid waste and pulverized coal. Liquid waste only was burned during the remaining two tests. Kilns production rates for Site II tests were typical for this facility. The following section discusses the operation of the kilns during the test program and presents the organic and inorganic composition of the waste fuels.

3.1 KILNS OPERATION

Table 4 summarizes the operation of the kilns during each test. For the most part, process information available at each site was limited to waste fuel flowrates and kiln production rates. Both kilns were insufficiently instrumented to permit recording of detailed process conditions. As stated earlier, three tests were performed at site I. Production rate of the kiln was maintained relatively constant during these three tests with the rotary kiln drying feed clay at approximately 50 percent moisture content to approximately 8 percent moisture at an estimated process temperature of between 593° to 650°C (1,122° to 1,200°F). The fuel burned during the tests was a mixture of waste oil and spent hydrocarbon solvents in a 20/80 percent blend that is typical of current site I practice. This waste fuel mixture, which accounted for all the fuel burned in the kiln, was preheated to a temperature ranging from 66° to 77°C (150° to 172°F) for tests 2 and 3 and 49° to 69°C (120° to 157°F) for test 1.

The measured flowrate of the waste fuel blend ranged from about 210 to 242 ml/s (222 to 230 gph) corresponding to a total heat input to the kiln of about 7.5 to 8.4 MW (25 to 29 million Btu/hr). Test 1 heat input was about 12 percent lower than either tests 2 or 3. This total heat input corresponds to about 67 to 77 percent of the kiln capacity. A production rate of about

TABLE 4. SUMMARY OF KILN OPERATION

Site	Test number	Kiln production kg/s (tons/hr)	Waste fuel flowrate, ml/s (gph)		Waste fuel heat input	
			Range	Test average	MW (million Btu/hr)[a]	Percent of total
I	1	~6.8 (27)[b]	205-216 (195-205)	210 (200)	7.45 (25.4)	100
	2	~7.6 (30)[b]	226-263 (215-250)	238 (226)	8.41 (28.7)	100
	3	~7.6 (30)[b]	220-252 (209-240)	237 (225)	8.39 (28.6)	100
II	1[c]	2.17 (8.62)	220-284 (209-270)	242 (230)	6.07 (20.7)	59
	2[c]	2.25 (8.94)	142-255 (135-243)	197 (187)	5.01 (17.1)	47
	3	2.19 (8.69)	270-348 (257-331)	315 (300)	8.50 (29.0)	100
	4	NA	270-354 (257-337)	318 (302)	8.71 (29.7)	100

[a] Calculated from the fuel higher heating values presented in Section 3-2

[b] Not a measured value

[c] Tests 1 and 2 correspond to kiln firing a combination of waste fuel and pulverized coal. During Tests 3 and 4, the waste fuel accounted for 100 percent of the fuel to the kiln.

NA -- Not available

7.6 kg/s (32 ton/hr) was estimated based on the calculated heat input and a kiln capacity of 10 kg/s (40 tons/hr).

Four tests were performed at site II with the kiln operating at near capacity. During tests 1 and 2, pulverized coal and waste fuel were fired in combination. The pulverized coal flowrate was estimated to be 0.13 and 0.17 kg/s (1,028 and 1,347 lb/hr) for tests 1 and 2, respectively, corresponding to a heat input of 4.22 MW (14.4 million Btu/hr) for test 1 and 5.60 MW (19.1 million Btu/hr) for test 2. Average waste fuel firing rate was higher for test 1, 242 ml/s (230 gph), than for test 2, 197 ml/s (187 gph). The average contribution of the waste fuel to the total heat input was nearly 60 percent during test 1, decreasing to below 50 percent for test 2.

During tests 3 and 4, the waste fuel contributed 100 percent of the total heat input to the kiln. Pulverized coal was not burned during these tests. The objective of these two tests was to compare the waste destruction under waste firing only condition versus the cofiring conditions of tests 1 and 2. The total waste fuel flowrate during these tests ranged from about 270 to 350 ml/s (260 to 330 gph), averaging approximately 315 ml/s (322 gph). The corresponding heat input averaged about 8.8 MW (30 million Btu/hr).

3.2 FUEL CHARACTERISTICS

Tables 5 through 7 summarize the proximate, ultimate, and trace element analyses results of fuel burned in the sites I and II kilns. The waste fuel burned in the kiln at site I was of relatively high heating value, about 40 MJ/kg (17,233 Btu/lb) consisting primarily of volatile organic matter (about 92 percent) and water (7.5 percent) with relatively minor quantity of inorganic ash (0.7 percent). Total chlorides in the waste fuel were on the order of 0.5 to 0.7 percent. Sulfur and nitrogen contents were 0.35 and 1.1 percent, respectively, similar to typical fuel oil concentrations. Analysis of inorganic elements in the waste fuel was limited to the 13 priority pollutant elements. For site I waste fuel, copper, lead, and zinc were detected in the highest concentrations ranging from 400 ppm for copper to nearly 700 ppm for lead.

Table 6 summarizes the analysis results for the pulverized bituminous coal burned at site II. Ash concentration averaged about 6 percent for both tests. The concentration of both sulfur and nitrogen were relatively low, 1 percent or less. Only copper, nickel, lead, and zinc were detected among the trace element priority pollutants. The concentration of these elements ranged between 5 and 25 ppm. Table 7 summarizes the analysis results for the waste fuel burned at site II. In contrast to site I, this waste fuel contained a much higher quantity of inorganic ash and water and consequently had a much lower heating value, on the order of 29 MJ/kg (12,000 Btu/lb). Total chloride concentration ranged from 1.1 to 2.56 percent averaging slightly above the 2 percent level. The waste fuel burned during the cofiring tests 1 and 2 contained slightly higher ash content and moisture than the same fuel burned during tests 3 and 4. This resulted in lower heating values of test 1 and 2 waste fuel. Total chlorides were also lower during these cofire tests than during the waste fuel only tests. Sulfur concentration was slightly lower than 0.2 percent with no significant difference between tests. Nitrogen content during tests 1 and 2 was 0.7 to 0.8 percent compared with 0.3 percent of tests 3 and 4.

Trace element priority pollutant analysis indicated a high concentration of lead, 700 to 975 ppm (890 ppm average). Other inorganics detected in concentrations greater than 100 ppm were chromium, copper, and zinc. Antimony, cadmium, mercury, and nickel were also detected in concentrations less than 10 ppm.

TABLE 5. WASTE FUEL ANALYSIS -- SITE I[a]

Composition	Test 1	Test 2	Test 3	Average
Proximate analysis, as received:				
Ash, percent	0.70	0.69	0.66	0.68
Moisture, percent	7.50	7.05	6.95	7.17
Volatile matter, percent[b]	98.49	98.56	98.52	98.52
Fixed carbon, percent	0.81	0.75	0.82	0.79
Higher heating value, MJ/kg	39.74	39.85	39.80	39.80
(Btu/lb)	(17,100)	(17,148)	(17,126)	(17,126)
Ultimate analysis, percent by weight as received:				
Chlorides[c]	0.60	0.64	0.74	0.66
Carbon	76.5	76.4	76.7	76.5
Hydrogen	12.7	12.6	12.7	12.7
Oxygen (by difference)	8.05	8.22	8.49	8.25
Sulfur	0.35	0.35	0.35	0.35
Nitrogen	1.1	1.1	1.1	1.1
Trace elements, ppm:				
Antimony, Sb	<1	<1	<1	<1
Arsenic, As	<1	<1	<1	<1
Beryllium, Be	<1	<1	<1	<1
Cadmium, Cd	1.1	1.0	1.0	1.0
Chromium, Cr	4.8	4.0	4.2	4.3
Copper, Cu	460	400	410	420
Lead, Pb	530	630	690	620
Mercury, Hg	<0.1	<0.1	<0.1	<0.1
Nickel, Ni	1.3	1.2	1.3	1.3
Selenium, Se	<1	<1	<1	<1
Silver, Ag	<1	<1	<1	<1
Thallium, Tl	<1	<1	<1	<1
Zinc, Zn	570	580	570	570
Specific gravity	0.890	0.888	0.888	0.889

[a] Each sample is a composite of four individual grab samples taken during each test.

[b] Volatile matter includes moisture.

[c] Total chloride in each sample by separate analysis indicates chloride concentration in the range of 0.35 to 0.54 percent with an average for all waste solvents of 0.46 percent.

TABLE 6. COAL ANALYSIS -- SITE II

Composition	Test 1	Test 2	Average
Proximate analysis, dry basis:			
Ash, percent	7.05	5.46	6.26
Moisture, percent (as received)	1.55	1.45	1.50
Volatile matter, percent	33.94	37.24	35.59
Fixed carbon, percent	59.01	57.30	58.16
Higher heating value, MJ/kg	32.44	33.02	32.73
(Btu/lb)	(13,960)	(14,209)	(14,085)
Ultimate analysis, percent dry basis:			
Carbon	77.1	76.9	77.0
Hydrogen	5.2	5.1	5.2
Oxygen (by difference)	9.1	10.3	9.7
Sulfur	0.70	1.30	1.0
Nitrogen	0.8	0.9	0.9
Trace elements, ppm:			
Cadmium, Cd	<1	<1	<1
Chromium, Cr	<5	<5	<5
Copper, Cu	10	15	13
Nickel, Ni	9	5	7
Lead, Pb	14	15	15
Zinc, Zn	25	6	15

TABLE 7. WASTE FUEL ANALYSIS -- SITE II[a]

Composition	Test 1[b]	Test 2[b]	Test 3[c]	Test 4[c]	Average
Proximate analysis, as received:					
Ash, percent	3.09	2.98	2.54	2.53	2.79
Moisture, percent	20.29	18.26	13.38	12.34	16.07
Volatile matter, percent	75.30	77.77	83.26	84.24	80.14
Fixed carbon, percent	1.32	0.99	0.82	0.89	1.01
Higher heating value, MJ/kg (Btu/lb)	27.18 (11,696)	28.37 (12,208)	30.45 (13,102)	31.06 (13,368)	29.27 (12,594)
Ultimate analyses, percent by weight as received:					
Chlorides[d]	1.10-2.02 (1.55)	1.85-2.12 (2.04)	2.20-2.32 (2.27)	2.12-2.56 (2.35)	1.10-2.56 (2.05)
Carbon	52.0	55.2	61.9	62.0	57.8
Hydrogen	10.5	11.0	10.6	10.5	10.7
Oxygen (by difference)	33.5	29.8	24.4	24.5	28.1
Sulfur	0.18	0.20	0.22	0.17	0.19
Nitrogen	0.7	0.8	0.3	0.3	0.5
Trace elements: ppm					
Antimony, Sb	9.4	9.0	8.0	9.4	9.0
Arsenic, As	<1	<1	<1	<1	<1
Beryllium, Be	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium, Cd	8.5	8.9	8.9	9.6	9.0
Chromium, Cr	140	130	175	130	126
Copper, Ca	92	90	92	105	95
Lead, Pb	750	975	900	950	890
Mercury, Hg	0.5	0.6	0.4	0.6	0.5
Nickel, Ni	2.9	2.7	2.7	2.9	2.8
Selenium, Se	<1	<1	<1	<1	<1
Silver, Ag	<0.5	<0.5	<0.5	<0.5	<0.5
Thallium, Tl	<1	<1	<1	<1	<1
Zinc, Zn	175	250	260	310	250
Specific gravity	0.9038	0.8977	0.8850	0.8823	0.8924

[a] Each sample is a composite of four individual grab samples taken during each test;

[b] Tests 1 and 2 correspond to a kiln firing a combination of pulverized coal and waste fuel.

[c] Tests 3 and 4 correspond to a kiln firing only waste fuel.

[d] Range in total chloride analysis is based on analytical results of individual samples taken during each test. Number in parenthesis are the corresponding arithmetic averages of these individual results.

SECTION 4

EMISSION RESULTS

The primary objective of the test program was to measure organic emissions in the exhaust gas stream of both kilns burning hazardous waste fuels containing POHC's to determine the destruction efficiency and identify PIC's. In addition to the organic sampling and analysis that was performed to determine POHC's DRE and PIC's formation, several other measurements of exhaust flue gas, liquid and solid waste streams were made to determine other multimedia pollutant emissions such as particulate, chlorides, and trace metals. Tables 8 and 9 summarize the sampling and analytical test matrices that were followed for the two test sites. Sample locations are highlighted in Figures 1 and 2 of Section 2.

The sampling protocol consisted of sample collection of all inlet and outlet streams. The flue gas was sampled downstream of particulate control devices, a fabric filter unit for site I and wet scrubber for site II. Continuous gas monitors were used to measure the concentration of O_2, CO_2, CO, NO/NO_x, and SO_2. Sampling of flue gas organics at site I consisted of both volatile organics using the volatile organic sampling train (VOST) and semivolatile and nonvolatile priority pollutant organics using a modified version of the EPA Method 5 (References 4-1 and 4-2, respectively). Organic analyses of samples collected were performed using gas chromatography with mass spectrometry (GC/MS). For site II, however, flue gas organic compound sampling was limited to the volatile fraction using the VOST. The standard EPA Method 5 sampling train was also used instead of the modified version to measure particulate emissions by gravimetric analysis and trace metal emissions by atomic absorption spectroscopy. HCl emissions were monitored at both sites using a modified version of the EPA Method 6 sampling train.

Liquid waste fuels were collected several times during each test and composited for organic and trace metals analyses using GC/MS and atomic absorption analytical procedures. GC/MS analyses were used to make concentration measurements for volatile and semivolatile priority organic pollutants as well as 1,1,2-trichloro, 2,2-1-trifluoroethane (Freon 113) which was artificially spiked in the waste fuels at both sites. Atomic absorbtion analyses were used for priority pollutant trace metals determination. Fuels were also subjected to standard ASTM analytical procedures for proximate and ultimate compositions including total chlorides. The proximate, ultimate, chlorides and trace metals analysis results of fuels were presented in Section 3.

TABLE 8. SAMPLING AND ANALYSIS PROTOCOL FOR SITE I ROTARY KILN CLAY DRYER

Sample/collection location	Type of sample/ monitoring equipment[a]	Number of samples[b]	Analysis[c]
Atmospheric flue gas emissions/ stack downstream of fabric filter	• Continuous monitors	Continuous (8 to 10 hr/test)	• O_2, CO_2, CO, NO/NO_x, SO_2
	• Modified EPA Method 5	3 (1 run/test)	• Semivolatile and nonvolatile organics by GC/MS
			• Particulate matter by gravimetry
			• Trace metals by atomic absorption
	• VOST	9 (3 runs/test)	• Volatile organics by GC/MS
	• Modified EPA Method 6	6 (2 runs/test)	• HCl by titration with silver nitrate
Fuel (waste oil and liquid burnable waste blend)/ fuel strainers	• Composite sample	3 (1 per test)	• C, H, N, O, S, and HHV by ASTM methods
			• Total chloride, ASTM P808
			• Volatile organics by GC/MS
			• Semivolatile and nonvolatile organics by GC/MS
			• Trace metals by atomic absorption
Fabric filter collected dust/ fabric filter hopper	• Composite sample	3 (1 per test)	No analysis performed

[a] Appendix A presents a detailed description of sampling equipment and protocols used.
[b] Does not include blanks, spikes, or other quality control samples.
[c] Appendix B presents a detailed description of analytical equipment and protocols used.

TABLE 9. SAMPLING AND ANALYSIS PROTOCOL FOR SITE II ROTARY AGGREGATE KILN

Sample/collection location	Type of sample/ monitoring equipment[a]	Number of samples[b]	Analysis[c]
Atmospheric flue gas emissions/ stack downstream of wet scrubber	• Continuous monitors	Continuous (8 to 10 hr/test)	• O_2, CO_2, CO, NO/NO_x, SO_2
	• EPA Method 5	12 (3 run/test)	• Particulate matter by gravimetry • Trace metals by atomic absorption
	• VOST	12 (3 runs/test)	• Volatile organics by GC/MS
	• Modified EPA Method 6	8 (2 runs/test)	• HCl by titration with silver nitrate
Liquid waste fuel/burner or fuel storage tank	• Composite sample	4 (1 per test)	• C, H, N, O, S, and HHV by ASTM methods • Total chloride, ASTM P808 • Volatile organics by GC/MS • Trace metals by atomic absorption
Coal/pulverized coal hopper	• Composite sample	2 (1 per test)	• Trace metals by atomic absorption • C, H, N, O, S and HHV by ASTM methods
Mechanical collector dust/ multicyclone hopper	• Composite sample	4 (1 per test)	No analysis performed
Wet scrubber influent and effluent/inlet and outlet of wet scrubber	• Composite sample	8 (1 per test for each stream)	• Volatile organics by GC/MS • Trace metals by atomic absorption • Total chlorides, ASTM P808

[a] Appendix A presents a detailed description of sampling equipment and protocols used

[b] Does not include blanks, spikes, or other quality control samples

[c] Appendix B presents a detailed description of analytical equipment and protocols used

Waste discharge streams from the particulate collection devices were also sampled. For site I, no analyses were performed on the fabric filter collected flyash. For site II, makeup water and slurry discharge were analyzed for volatile organics, selected trace metals, and chlorides. Appendices A and B discuss in greater detail all sampling and analysis equipment and procedures implemented during this test program.

The following sections discuss the results obtained for criteria gas emissions and total chlorides detected in both flue gas and air pollution control devices waste discharge streams. Section 5 presents flue gas emission results and POHC DRE's for both kilns. Section 6 summarizes results obtained for trace metals detected in all discharge streams at both test sites.

4.1 CRITERIA GAS EMISSIONS

Tables 10 and 11 summarize emission results obtained at sites I and II, respectively for O_2, CO_2, CO, NO_x, and SO_2. The rotary kiln clay dryer at site I operated with very high excess air levels of about 280 percent. CO emissions as measured (at about 16 percent excess O_2) ranged between 15 to 110 ppm. Test average SO_2 and NO_x emissions were also relatively low ranging from about 13 to 44 ppm as measured for SO_2 and 56 to 66 ppm for NO_x.

The sulfur content of the waste fuel at site I was 0.35 percent (see Table 5). A complete conversion of this sulfur level to SO_2 corresponds to about 175 ng/J (40 ppm at 16 percent O_2) in the flue gas. Therefore, the monitored SO_2 emissions correspond to about 30 to 100 percent of the total sulfur in the waste fuel. Low sulfur conversions measured by the gas monitors may be attributed to partial SO_2 retention in the clay or in the entrained dust collected by the fabric filter unit.

Excess O_2 during testing on the rotary aggregate kiln at site II ranged from 7.5 to nearly 10 percent corresponding to about 50 to 80 percent excess combustion air. Excess combustion air levels were slightly higher during the cofiring with both coal and waste fuel than with waste fuel combustion only. Sulfur dioxide emissions were found to be unexpectedly high, often exceeding the 1,000 ppm level. This was especially surprising for the waste fuel only tests 3 and 4 because of the low sulfur concentration in the waste fuel. Table 12 summarizes the results of the sulfur balance analysis for site II. As indicated, the measured flue gas SO_2 was significantly higher than what could be accounted for by either fuel. The flue gas SO_2 was 3 to 4 times the amount resulting from that input to the system in fuel for tests 1 and 2 and 9 to 12 times for tests 3 and 4. The only plausible explanation for this apparent sulfur imbalance may be a contribution of the aggregate material in the kiln to the flue gas SO_2. However, even this possibility does not account for sulfur removal by the wet scrubber.

Test average NO_x emissions were about 134 ppm for test 1 increasing to 156 ppm corrected to 15 percent O_2 during test 2. The increase in NO_x during test 2 is attributed to a greater coal contribution to the total heat input during this test, 53 percent versus 41 percent (see Table 4). Nitrogen

TABLE 10. CONTINUOUSLY MONITORED CRITERIA GASEOUS EMISSIONS -- SITE I

Date	Test number	As measured concentrations, dry basis					Corrected to 15 percent O_2, dry basis		
		O_2 (percent)	CO_2 (percent)	CO (ppm)	SO_2 (ppm)	NO_x (ppm)	CO (ppm)	SO_2 (ppm)	NO_x (ppm)
2/14/84	1	14.9 to 16.6 (15.5)[b]	2.6 to 4.0 (3.4)	--[a] --	12 to 33 (23)	55 to 74 (66)	-- --	13 to 36 (25)	60 to 81 (72)
2/15/84	2	15.3 to 16.4 (16.1)	2.5 to 3.7 (3.0)	15 to 105 (50)	33 to 53 (44)	51 to 63 (57)	18 to 129 (61)	41 to 65 (54)	63 to 77 (70)
2/16/84	3	15.8 to 16.3 (16.0)	2.8 to 3.2 (3.0)	25 to 110 (57)	3 to 22 (13)	49 to 59 (56)	30 to 132 (69)	4 to 26 (16)	59 to 71 (67)

[a] Moisture contamination in CO cell, thus no data were obtained.

[b] Numbers in parentheses are test averages of recorded measurements.

TABLE 11. CONTINUOUSLY MONITORED CRITERIA GASEOUS EMISSIONS -- SITE II

		As measured concentrations, dry basis				Corrected to 15 percent O_2, dry basis	
Date	Test number	O_2 (percent)	CO_2 (percent)	SO_2 (ppm)	NO_x (ppm)	SO_2 (ppm)	NO_x (ppm)
3/6/84	1[a]	8.5 to 11.0 (9.8)[b]	6.0 to 8.8 (7.5)	720 to 1200 (922)	195 to 345 (252)	383 to 638 (490)	104 to 183 (134)
3/7/84	2[a]	5.0 to 10.0 (8.0)	8.3 to 13.1 (10.0)	1100 to 1840 (1480)	207 to 460 (340)	503 to 842 (677)	95 to 210 (156)
3/8/84	3	6.0 to 10.0 (7.7)	7.6 to 11.9 (9.7)	872 to 1579 (1284)	210 to 265 (240)	390 to 706 (574)	94 to 116 (107)
3/9/84	4	5.0 to 9.8 (7.5)	6.7 to 11.2 (9.1)	1180 to 1583 (1368)	210 to 280 (245)	520 to 697 (602)	92 to 123 (107)

[a] Cofired tests (coal and waste fuel).
[b] Numbers in parentheses are test averages of recorded measurements.

TABLE 12. SULFUR BALANCE -- SITE II

Test number	Sulfur input[a] 10^{-3} kg/s (lb/hr)	SO_2 conversion ng/J (lb/10^6Btu)	Average SO_2 emissions ppm, dry	Average SO_2 emissions ng/J (lb/10^6Btu)	Sulfur balance $\frac{SO_2\ out}{SO_2\ in}$
1	1.30 (10.3)	253 (0.59)	922	1,030 (2.40)	4.1
2	2.56 (20.3)	480 (1.12)	1,480	1,570 (3.64)	3.3
3	0.59 (4.7)	139 (0.32)	1,284	1,290 (3.01)	9.3
4	0.48 (3.8)	110 (0.26)	1,364	1,350 (3.13)	12
Average	1.23 (9.78)	245 (0.56)	1,263	1,310 (3.05)	7.2

[a] Sulfur input from combined coal and waste fuel for tests 1 and 2 and for waste fuel only for tests 3 and 4. (Sulfur entering the system in the aggregate is not included in this value.)

content of the coal was about 0.9 percent versus only 0.3 percent for the waste fuel. Average NO_x emissions during tests 3 and 4 (waste fuel only) was about 107 ppm corrected to 15 percent O_2. These lower NO_x levels are due to switching from the coal/waste cofiring mode of tests 1 and 2 to waste fuel firing only.

4.2 PARTICULATE EMISSIONS

Tables 13 and 14 summarize particulate test data for the kilns at site I and site II, respectively. Particulate emissions were measured at the control device outlet at both sites. For site I, particulate concentration in the stack flue gas ranged from 0.83 to 1.9 mg/dscm (0.0004 to 0.0008 gr/dscf). The lowest concentration was recorded during test 2. Particulate concentrations in the stack flue gas at site II were significantly higher than those measured at site I as indicated in Table 14. Particulate concentration during the coal/waste fuel cofired tests 1 and 2 ranged from about 174 to 466 mg/dscm (0.076 to 0.203 gr/dscf). Test 1 particulate emissions were much higher than any of the other tests due to significant moisture entrainment from the wet scrubber. This is indicated by the measured moisture content of the flue gas. Following test 1, the operation of the scrubber was adjusted to reduce this moisture entrainment.

Tables 15 and 16 summarize the total particulate emission rate. Site I particulate emissions averaged 15.5 mg/s (0.12 lb/hr) corresponding to a mass emission rate of only 2×10^{-3} kg per metric ton (MT) of product based on a production estimate of about 7.6 kg/s (30 tons/hr) of clay. Site II emission rates ranged from a high of about 1,700 mg/s (13.43 lb/hr) for test 1 to a low of 556 mg/s (4.44 lb/hr) for test 2. These emissions correspond to a mass emission rate of 0.779 kg/MT (1.56 lb/ton) of aggregate product for test 1 and 0.248 kg/MT (0.497 lb/ton) for test 2. Particulate emission rates for tests 3 and 4 were slightly higher than those of test 2 indicating that coal contributions to these emissions may be insignificant compared to contributions from the aggregate product and scrubber operation.

4.3 CHLORIDE EMISSIONS

Total chlorides as HCl were measured in the stack flue gas at both kilns. Tables 17 and 18 summarize HCl emissions. Two separate measurements were made during each test. Site I test average emissions ranged from 0.18 to 0.30 g/s (1.42 to 2.32 lb/hr). Total estimated chloride input into the kiln dryer at this site was estimated at 0.67 to 1.1 g/s (5.3 to 9.0 lb/hr) based on the chloride concentration in the waste fuel ranging from 0.35 to 0.54 percent and a firing rate of 0.19 to 0.21 kg/s (1,480 to 1,670 lb/hr). Therefore, total chlorine measured in the stack flue gas as HCl represented about 25 to 30 percent of the total chlorine fired with the waste fuel. It is not known whether HCl was absorbed by the entrained dust in the baghouse or by the clay in the kiln.

Site II test average chloride emissions ranged from about 0.9 to 1.1 g/s (7.2 to 8.6 lb/hr) for tests 1 and 2, respectively. Lower chloride emissions were measured during tests 3 and 4 when waste fuel contributed 100 percent of

TABLE 13. SUMMARY OF PARTICULATE EMISSIONS TEST DATA -- SITE I

Date	Test no.	Test time	Stack gas moisture, percent	Stack gas temperature, °C (°F)	Stack gas velocity, m/s (ft/sec)	Sample volume, dscm (dscf)	Particulate catch (mg)		Particulate concentration, mg/dscm (gr/dscf)	Isokinetic, percent
							Filter	Probe and nozzle		
2-14-84	1	1500-1815 1930-2050	28.6	79 (174)	17.9 (58.7)	3.63 (128.2)	4.74	2.17	1.9 (0.0008)	95.6
2-15-84	2	1400-2030	28.2	73 (163)	16.4 (3.8)	9.81 (346.3)	4.22	3.97	0.83 (0.0004)	99.2
2-16-84	3	1010-1630	24.7	76 (168)	16.8 (5.2)	9.93 (350.8)	9.84	7.05	1.7 (0.0007)	94.6
	Average		27.2	76 (168)	17.0 (55.9)	7.79 (275.1)	6.27	4.37	1.48 (0.0006)	--

TABLE 14. SUMMARY OF PARTICULATE EMISSIONS TEST DATA -- SITE II

Date	Test[a] no.	Test time	Stack gas moisture (percent)	Stack gas temperature (°F)	Stack gas velocity (ft/sec)	Sample volume (dscf)	Particulate catch (mg)		Particulate concentration (gr/dscf)	Isokinetic (percent)
							Filter	Probe and nozzle		
3-6-84	1A	1052-1206	13.1	130	32.0	64.69	443.9	408.8	0.203	105.0
	1B	1421-1535	11.9	130	26.4	30.35	157.2	116.8	0.139	110.8
	1C	1749-1856	12.3	131	25.2	52.17	323.7	208.6	0.158	106.9
	Ave	--	12.4	130	27.9	--	--	--	0.167	--
3-7-84	2A	0939-1045	9.0	125	18.0	36.92	153.2	34.1	0.078	99.8
	2B	1306-1415	9.9	121	18.9	38.41	151.6	38.3	0.076	99.2
	2C	1601-1708	9.8	124	19.0	38.34	157.9	48.3	0.083	99.1
	Ave	--	9.6	123	18.6	--	--	--	0.079	--
3-8-84	3A	0910-1020	9.5	125	18.8	39.12	219.5	21.4	0.081	101.9
	3B	1241-1248	10.0	126	18.9	38.60	248.3	12.2	0.104	101.1
	3C	1556-1703	9.4	125	18.3	38.21	265.9	13.4	0.113	101.9
	Ave	--	9.6	125	18.7	--	--	--	0.099	--
3-9-84	4A	0947-1057	9.4	124	18.6	38.73	299.4	13.1	0.125	101.4
	4B	1251-1358	9.8	124	18.5	37.01	222.3	12.7	0.098	97.4
	4C	1546-1651	9.1	122	19.0	39.37	187.9	16.2	0.080	99.8
	Ave	--	9.4	123	18.7	--	--	--	0.101	--

[a] Three separate EPA Method 5 measurements were made for each test. Tests 1 and 2 represent cofired tests with a combination of pulverized coal and waste fuel.

TABLE 15. SUMMARY OF PARTICULATE EMISSIONS -- SITE I

Date	Test No.	Flue gas volumetric flowrate m^3/s (dscfm)	Particulate concentration mg/dscm (gr/dscf)	Particulate mg/s (lb/hr)	Mass emission rate kg/MT (lb/ton)[a]
2-14-84	1	10.4 (22.1)	1.90 (0.0008)	20.2 (0.16)	0.003 (0.006)
2-15-84	2	9.9 (20.9)	0.83 (0.0004)	8.8 (0.07)	0.001 (0.002)
2-16-84	3	10.5 (22.3)	1.70 (0.0007)	17.6 (0.14)	0.003 (0.005)
	Average	10.3 (21.8)	1.48 (0.0006)	15.5 (0.12)	0.002 (0.004)

[a] Mass emission rate per mass production rate of kilns.

TABLE 16. SUMMARY OF PARTICULATE EMISSIONS -- SITE II

Date	Test No.	Flue gas volumetric flowrate m^3/s (10^3 dscfm)	Particulate concentration mg/dscm (gr/dscf)	Particulate mg/s (lb/hr)	Mass emission rate kg/MT (lb/ton)[a]
3-6-84	1A	5.0 (10.6)	466.0 (0.203)	2,330 (18.43)	1.070 (2.14)
	1B	4.2 (8.8)	318.6 (0.139)	1.338 (10.54)	0.611 (1.22)
	1C	4.0 (8.4)	359.7 (0.158)	1,439 (11.31)	0.655 (1.31)
	Average	4.4 (9.27)	381.4 (0.167)	1,702 (13.43)	0.779 (1.56)
3-7-84	2A	3.0 (6.3)	178.4 (0.078)	535 (4.26)	0.238 (0.477)
	2B	3.1 (6.6)	174.2 (0.076)	540 (4.34)	0.243 (0.485)
	2C	3.1 (6.6)	191.0 (0.083)	592 (4.72)	0.264 (0.528)
	Average	3.1 (6.5)	181.2 (0.079)	556 (4.44)	0.248 (0.497)
3-8-84	3A	3.1 (6.6)	217.0 (0.081)	673 (4.57)	0.263 (0.526)
	3B	3.1 (6.5)	239.0 (0.104)	741 (5.84)	0.336 (0.672)
	3C	3.0 (6.4)	258.7 (0.113)	776 (6.22)	0.358 (0.716)
	Average	3.1 (6.5)	238.2 (0.099)	730 (5.54)	0.319 (0.638)
3-9-84	4A	3.1 (6.6)	284.0 (0.125)	880 (6.99)	NA
	4B	3.1 (6.5)	223.8 (0.098)	694 (5.48)	
	4C	3.2 (6.8)	182.2 (0.080)	583 (4.64)	
	Average	3.1 (6.6)	230.0 (0.101)	713 (5.70)	

[a] Mass emission rate per mass production rate of kilns.

NA -- Not available; no process data was recorded for this test.

TABLE 17. SUMMARY OF CHLORIDE EMISSIONS -- SITE I

Test number	Run	Total chloride (mg)	Flue gas volume sampled, m^3 (ft^3)	HCl emission rate g/s (lb/hr) Run specific	HCl emission rate g/s (lb/hr) Test average
1	A	19.1	0.61 (21.6)	0.33 (2.59)	0.23 (1.78)
	B	8.2	0.71 (25.1)	0.12 (0.96)	
2	A	32.9	0.67 (23.5)	0.49 (3.87)	0.30 (2.32)
	B	6.5	0.66 (23.2)	0.10 (0.77)	
3	A	7.6	0.72 (25.6)	0.11 (0.88)	0.18 (1.42)
	B	14.3	0.61 (21.6)	0.25 (1.95)	

TABLE 18. SUMMARY OF CHLORIDE EMISSIONS -- SITE II

Test number	Run	Total chloride (mg)	Flue gas volume sampled, m^3 (ft^3)	HCl emission rate g/s (lb/hr) Run specific	HCl emission rate g/s (lb/hr) Test average
1	A	185.5	0.78 (27.5)	1.04 (8.27)	0.90 (7.16)
	B	134.6	0.77 (27.3)	0.76 (6.05)	
2[a]	A	--	--	--	
	B	271.1	0.76 (27.0)	1.09 (8.63)	1.09 (8.63)
3	A	144.6	0.76 (26.9)	0.58 (4.62)	0.50 (3.94)
	B	103.2	0.77 (27.3)	0.41 (3.25)	
4	A	137.2	0.77 (27.2)	0.55 (4.40)	0.70 (5.55)
	B	205.8	0.76 (26.8)	0.84 (6.70)	

[a] Sample lost during transport

the heat input to the kiln. Total chlorine input during tests 1 and 2 ranged from about 3.3 to 4.4 g/s (26 to 35 lb/hr). Therefore, total chloride emissions accounted for about 25 to 28 percent of the total chlorine input by the waste fuel. A combination of chlorine absorption in the aggregate as well as HCl scrubbing by the wet scrubber may have contributed to this mass imbalance. HCl emissions during tests 3 and 4 accounted for only 10 percent, or lower, of the total chlorine fired with the waste fuel.

At site II, scrubber wastewater discharge and makeup water were also analyzed for total chloride concentration. Table 19 summarizes the results of these analyses and presents the calculated chloride flowrate based on estimates of mass discharge rate from the scrubber. Total chloride concentration in the scrubber discharge ranged from 400 to 650 mg/l. During tests 1 and 2, the chloride flowrate in the scrubber discharge ranged from about 2.5 to 5.1 g/s (20 to 40 lb/hr). These emission rates compare favorably with the input rate to the kiln which was calculated in the range of 3.3 to 4.4 g/s (26 to 35 lb/hr). This indicated that the scrubber discharge actually accounted for nearly all the chloride input during tests 1 and 2. Similarly, for tests 3 and 4, the scrubber discharge rate of chlorides ranged between 3.8 and 6.1 g/s (30 to 49 lb/hr). This compares with the calculated input rate of about 5.9 to 6.8 g/s (47 to 54 lb/hr) during these two tests.

TABLE 19. TOTAL CHLORIDE CONCENTRATION IN SCRUBBER INLET AND OUTLET STREAMS -- SITE II

Test number	Scrubber inlet concentration, mg/l	Scrubber outlet concentration, mg/l	Total chloride emissions, g/s (lb/hr)[a]
1	6	540	3.36 to 5.07 (26.6 to 40.2)
2	5	400	2.49 to 3.75 (19.7 to 29.7)
3	6	610	3.81 to 5.74 (30.2 to 45.5)
4	6	650	4.06 to 6.12 (32.2 to 48.5)

[a] Based on estimated water throughput of 6.3 to 9.5 l/s (100 to 150 gpm)

REFERENCES FOR SECTION 4

4-1. "Protocol for the Collection and Analysis of Volatile POHC's Using VOST," EPA-600/8-84-007, March 1984.

4-2. Harris, J. C. et al., "Sampling and Analysis Methods for Hazardous Waste Incineration," prepared by Arthur D. Little, Inc., EPA Contract No. 68-02-3111, February 1982.

SECTION 5

ORGANIC SPECIES EMISSIONS AND DRE'S

This section presents results specific to organic species emissions and the destruction of POHC's and other major organics in the waste fuels burned in the two rotary kilns.

5.1 WASTE FUEL ORGANIC ANALYSES

Waste fuel samples were collected and composited during each test at both site I and site II for subsequent laboratory analysis for organic compound concentrations. Laboratory analytical procedures focused on the identification and quantitation of volatile, semivolatile, and nonvolatile organic priority pollutants and RCRA Appendix VIII organics (POHC's) using gas chromatography with mass spectrometry (GC/MS). The compound, 1,1,2-trichloro-2,2,1-trifluorethane (Freon 113) added to the waste was also specifically sought in the analyses of both fuel and emission samples. This compound was artificially added to the waste fuels burned during this program to permit a direct comparison of DRE results between the two test sites and also to investigate the feasibility of using Freon 113 as a surrogate for DRE measurements of POHC's and other major organics.

Tables 20 through 23 summarize the concentrations of organics detected in the waste fuels at both test sites. Table 20 summarizes the volatile organic compounds in the waste fuel blend at site I. Among the RCRA Appendix VIII compounds (POHC's), toluene was found to have the highest concentration averaging about 0.89 mg/ml (or 1,000 ppm by weight). Other volatile POHC's having concentrations in the range of 300 to 400 ppm were 1,1,1-trichloroethane, and 2-butanone (methyl-ethyl-ketone). Trichloroethylene (TCE), benzene, tetrachloroethylene (PCE), and chlorobenzene were detected in the range of about 10 to 150 ppm. The concentration of Freon 113 averaged 6 mg/ml (about 7,000 ppm or 0.4 percent by weight), corresponding approximately to the anticipated concentration of 0.5 percent by volume following the spiking of the waste at the site.

Table 21 summarizes waste fuel concentration of semivolatile organics at site I. Naphthalene and phthalate compounds were the only POHC's detected. Other organics were xylenes, methylnapthalenes, and methyl benzenes in concentrations ranging from 0.15 to 2.3 mg/ml (170 to 2,600 ppm by weight).

Table 22 summarizes the volatile organics in the waste fuel at site II for all four tests. Among the RCRA Appendix VIII compounds, toluene was

TABLE 20. VOLATILE ORGANICS IN THE FEED -- SITE I-

Compound	Concentration, mg/ml[a]			
	Test 1	Test 2	Test 3	Average
RCRA Appendix VIII:				
1,1,1-trichloroethane	0.364	0.346	0.355	0.355
Trichloroethylene	0.038	0.036	0.032	0.035
Benzene	0.037	0.057	0.046	0.047
Tetrachloroethylene	0.147	0.149	0.121	0.139
Toluene	0.925	0.912	0.825	0.887
Chlorobenzene	0.014	0.011	0.011	0.012
2-butanone (MEK)	0.390	0.305	0.398	0.364
Others:				
Ethylbenzene	0.521	0.517	0.478	0.505
Acetone	5.08	3.98	4.94	4.67
Ethanol	31.0	26.3	30.8	29.4
Styrene	0.056	0.039	0.038	0.044
Xylenes	2.21	2.19	2.09	2.16
1,1,2-trichloro-2,2,1-trifluoroethane (Freon 113)[b]	5.94	5.92	6.10	6.00
C3-alkylbenzene	0.331	0.276	0.169	0.259
Detection limit	0.003	0.003	0.003	0.003

[a] Each test sample represents a composite of four separate samples

[b] Freon 113 was artificially added to the typical waste fuel at this site by adding 284 liters of Freon 113 to 56,800 liters of waste fuel (75 gal of Freon 113 to 15,000 gal) to investigate its incinerability

TABLE 21. SEMIVOLATILE ORGANICS IN THE FEED -- SITE I

Compound	Concentration, mg/ml[a]			
	Test 1	Test 2	Test 3	Average
RCRA Appendix VIII:				
Naphthalene	0.72	0.77	0.73	0.74
Dibutylphthalate	0.18	0.28	0.57	0.34
Bis(2-ethylhexyl)phthalate	ND	ND	0.25	0.08
Others:				
Butyl acetate	0.83	1.5	1.2	1.2
2-methylnaphthalene	0.61	0.68	0.67	0.65
Xylenes	2.3	2.3	1.9	2.2
Ethylmethylbenzene	0.67	0.65	0.65	0.65
Trimethylbenzene	1.4	1.4	1.3	1.4
Ethyl-dimethylbenzene	0.40	0.40	0.40	0.40
Tetramethylbenzene	0.30	0.40	0.30	0.33
Dimethylnaphthalene	1.0	1.0	1.3	1.1
Trimethylnaphthalene	0.20	0.26	0.15	0.20
Detection limit	0.1	0.1	0.1	0.1

[a] Each test sample represents a composite of four separate samples

ND -- Not detected

TABLE 22. WASTE SOLVENT VOLATILE ORGANICS -- SITE II

Compound	Concentration, mg/ml[a]				
	Test 1	Test 2	Test 3	Test 4	Average
RCRA Appendix VIII:					
Dichloromethane	3.99	4.28	4.96	4.92	4.54
1,2-dichloroethane	0.117	0.117	0.130	0.140	0.126
1,1,1-trichloroethane	1.45	1.63	2.01	2.03	1.78
Carbon tetrachloride	0.059	0.065	0.083	0.082	0.072
1,2-dichloropropane	0.010	0.012	0.008	0.013	0.011
Trichloroethylene	0.543	0.636	0.442	0.732	0.588
Benzene	0.094	0.111	0.078	0.131	0.103
Tetrachloroethylene	2.45	2.94	2.11	3.53	2.76
Toluene	36.8	37.8	26.6	43.7	36.2
Chlorobenzene	0.147	0.148	0.119	0.184	0.149
2-butanone (MEK)	11.4	15.8	13.2	14.1	13.6
Others:					
Chloroethane	2.50	2.90	3.35	3.50	3.06
Ethylbenzene	16.6	19.6	14.9	24.0	18.8
Styrene	1.11	1.25	0.830	1.40	1.15
Xylenes	64.6	69.7	51.7	84.1	67.5
1,1,2-trichloro-2,2,1-trifluoroethane (Freon 113)[b]	5.86	7.63	8.90	8.98	7.84
C_3-alkylbenzene	1.69	1.85	1.35	2.26	1.79
4-methyl-2-pentanone	9.12	12.3	7.38	12.3	10.3
Di-isopropylether	>4.60	>4.60	>4.60	>4.60	>4.60
Detection limits	0.002	0.002	0.002	0.002	0.002

[a] Each test sample represents a composite of four separate samples.

[b] Freon 113 was artifically added to the typical waste fuel at this site by adding 416 liters of Freon 113 to 73,800 liters of waste fuel (100 gal of Freon 113 to 19,500 gal) to investigate its incinerability

TABLE 23. WASTE SOLVENT SEMIVOLATILE ORGANICS -- SITE II

	Concentration, mg/ml[a]				
Compound	Test 1	Test 2	Test 3	Test 4	Average
RCRA Appendix VIII:					
Phenol	2.90	2.75	2.79	2.53	2.74
1,3-dichlorobenzene	0.180	0.195	0.230	0.220	0.206
1,4-dichlorobenzene	1.36	1.46	1.68	1.63	1.53
1,2-dichlorobenzene	5.42	5.88	6.33	6.22	5.96
2,4-dimethylphenol	0.780	0.770	1.02	0.910	0.870
Naphthalene	1.04	1.17	1.31	1.35	1.22
Others:					
4-methylphenol	1.16	1.14	1.21	1.05	1.14
2-methylphenol	0.620	0.620	0.680	0.610	0.632
2-methylnaphthalene	0.10	0.10	0.13	0.13	0.115
Xylenes	18.0	18.0	18.0	25.7	19.9
Ethylmethylbenzene	1.50	1.50	2.00	2.00	1.75
Trimethylbenzene	3.00	3.00	3.00	2.60	2.90
Methylpropylbenzene	0.80	1.00	0.90	0.90	0.90
Tetramethylbenzene	1.80	1.80	1.80	1.80	1.80
Hydrocarbons	7.0	7.5	8.2	8.0	7.7
Propylbenzene	0.75	1.0	1.0	0.90	0.91
Diethylbenzene	0.50	0.50	0.50	0.50	0.50
Detection limits	0.1	0.1	0.1	0.1	0.1

[a] Each test sample represents a composite of four separate samples

again found in the highest concentration, ranging from about 27 to 44 mg/ml (about 30,000 to 49,000 ppm by weight). Chlorinated POHC's having concentrations greater than 500 ppm were dichloromethane (methylene chloride) with concentrations ranging from about 4 to 5 mg/ml, 1,1,1-trichloroethane (1.45 to 2.03 mg/ml), trichloroethylene (0.44 to 0.73 mg/ml) and tetrachloroethylene (2.11 to 3.53 mg/ml). Other major organics detected were xylenes, ethylbenzene, 4-methyl-2-pentanone, Freon 113, chloroethane styrene, C_3-alkylbenzene, and di-isopropylether, all in concentrations greater than 1,000 ppm. The concentration of Freon 113 ranged from about 5.9 to 8.9 mg/ml corresponding to about 0.37 to 0.56 percent on a volume basis. The anticipated concentration of Freon 113 following spiking of the waste fuel at this site was 0.56 percent by volume.

Table 23 summarizes the concentration of semivolatile organics detected in the site II waste fuel. Semivolatile POHC's were phenol, various isomers of dichlorobenzene, 2,4-dimethylphenol, and naphthalene, having concentrations in the range of 0.18 to 6.33 mg/ml, corresponding to about 200 to 7,100 ppm by weight. Several other organics were detected with xylenes having the highest concentration of about 18 to 26 mg/ml (22,000 to 28,000 ppm).

The following sections summarize the flue gas emissions and DRE results obtained for organic compounds detected in the waste fuel. In order to facilitate presentation and interpretation of these results, the data are presented according to each test site. Comparative analyses of results obtained between the two rotary kilns are presented in Section 5.4.

5.2 SITE I RESULTS

Flue gas sampling for organic emissions at site I included measurements for volatile organic compounds and semivolatile and nonvolatile organics. Three separate measurements for volatile organics were made for each of the three tests at this site. VOST samples also included several sets of analytical blanks identified as field, trip, and laboratory blanks. Field blanks were prepared for each test day whereas only one set each of trip and laboratory blanks were prepared for the test program at site I. Semivolatile organic sampling was performed once per test. Each test also included an organic sorbent blank.

The following sections summarize the emission results, the DRE's of POHC's and other major organics in ten waste fuels, and the identifiable products of incomplete combustion.

5.2.1 Emission Results

Tables 24 through 26 summarize emission results for volatile organics for each of the three tests at this site. With the exception of chloromethane and dichloromethane (methylene chloride), the VOST blank samples were generally found to be void of significant quantity of POHC's. Acetone and isopropanol were the other sources of contamination for VOST Tenax traps. In general, volatile organic emissions during test 1 were

TABLE 24. VOLATILE ORGANIC EMISSIONS, TEST 1 -- SITE I

	Trap concentrations (A+B)[a], ng						
	Sample			Blanks			Test average emission rate[b] (μg/s)
Compound	Run 1	Run 2	Run 3	Field	Trip	Lab	
RCRA Appendix VIII:							
Chloromethane	239	483	179	453	95, 212	83	4.5
Bromomethane	29	ND	20	ND	ND, ND	ND	7.7
Vinylchloride	206	52	26	ND	ND, ND	ND	44
Dichloromethane	217	339	112	79	73, 65	48	72
1,1-dichloroethane	72	200	61	ND	ND, ND	ND	55
Chloroform	18	7	3	ND	ND, 1	ND	3.9
1,1,1-trichloroethane	94	195	116	6	ND, ND	20	57
Carbon tetrachloride	335	1,870	884	51	ND, ND	ND	494
Trichloroethylene	50	46	19	ND	ND, ND	9	14
Benzene	8,500	322	345	10	ND, 7	ND	1,380
Tetrachloroethylene	177	84	19	ND	ND, ND	6	41
Toluene	2,780	577	416	12	5, 10	9	580
Chlorobenzene	57	31	21	ND	ND, ND	ND	18
2-butanone (MEK)	4	10	345	ND	ND, ND	ND	61
Others:							
Ethylbenzene	389	56	55	2	ND, ND	4	76
Acetone	29	58	420	3	ND, 4	108	53
Isopropanol	146	ND	ND	276	ND, 326	ND	--
Styrene	272	137	130	1	ND, 1	4	85
Xylenes	1,260	222	216	5	ND, 3	4	262
Freon 113	578	255	103	10	ND, 2	ND	143
C_3-alkylbenzene	ND	ND	134	ND	ND, ND	ND	23

[a] Total amount collected in both trap A (Tenax) and trap B (Tenax/charcoal)

[b] Emissions are blank corrected using the highest background contamination in either the field, trip, or laboratory blanks

ND -- Not detected, detection limit = 1 ng/trap

TABLE 25. VOLATILE ORGANIC EMISSIONS, TEST 2 -- SITE I

Compound	Trap concentrations (A+B)[a], ng						Test average emission rate[b] (μg/s)
	Sample			Blanks			
	Run 1	Run 2	Run 3	Field	Trip	Lab	
RCRA Appendix VIII:							
Chloromethane	284	388	199	65	95, 212	83	67
Bromomethane	17	16	34	ND	ND, ND	ND	11
Vinyl chloride	26	33	68	ND	ND, ND	ND	21
Chloroethane	ND	ND	25	ND	ND, ND	ND	4.1
Dichloromethane	178	53	63	62	73, 65	48	17
Chloroform	16	3	3	ND	ND, ND	ND	3.6
1,1,1-trichloroethane	98	140	56	1	10, 1	20	38
Carbon tetrachloride	35	82	7	ND	ND, ND	ND	20
1,2-dichloropropane	ND	6	11	ND	ND, ND	ND	2.8
Trichloroethylene	13	3	ND	ND	ND, ND	9	--
1,1,2-trichloroethylene	ND	2	ND	ND	ND, ND	3	--
Benzene	450	233	501	ND	6, 7	ND	190
Tetrachloroethylene	27	17	9	ND	ND, ND	6	5.6
1,1,2,2-tetrachloroethane	ND	16	ND	ND	ND, ND	ND	2.6
Toluene	511	351	444	3	5, 10	9	210
Chlorobenzene	38	26	43	ND	ND, ND	ND	17
2-butanone (MEK)	158	21	41	ND	ND, ND	ND	35
Others:							
Ethylbenzene	121	54	89	ND	ND, ND	4	41
Acetone	619	255	255	ND	ND, 4	108	130
Styrene	49,400	1,990	893	ND	ND, 1	4	8,500
Xylenes	362	274	375	ND	ND, 3	4	165
Freon 113	40	81	39	ND	ND, 2	ND	26
C_3-alkylbenzene	777	363	197	ND	ND, ND	ND	220

[a] Total amount collected in both trap A (Tenax) and trap B (Tenax/charcoal)

[b] Emissions are blank corrected using the highest background level in either the field, trip, or laboratory blanks

ND -- Not detected, detection limit = ng/l trap

TABLE 26. VOLATILE ORGANIC EMISSIONS, TEST 3 -- SITE I

	Trap concentrations (A+B)[a], ng						
	Sample			Blanks			Test average emission rate[b] (µg/s)
Compound	Run 1	Run 2	Run 3	Field	Trip	Lab	
RCRA Appendix VIII:							
Chloromethane	292	131	128	127	95, 212	83	24
Bromomethane	16	15	ND	ND	ND, ND	ND	5.2
Vinyl chloride	25	43	39	ND	ND, ND	ND	18
Dichloromethane	77	84	38	91	73, 65	48	--
Chloroform	3	2	2	22	ND, ND	ND	--
1,1,1-trichloroethane	27	35	113	58	ND, 1	20	9.4
Carbon tetrachloride	9	7	ND	ND	ND, ND	ND	4.1
Trichloroethylene	ND	1	1	ND	ND, ND	9	--
Benzene	221	267	242	5	ND, 7	ND	122
Tetrachloroethylene	6	5	6	ND	ND, ND	6	--
Toluene	404	414	351	3	5, 10	9	200
Chlorobenzene	28	40	34	ND	ND, ND	ND	18
2-butanone (MEK)	37	24	21	ND	ND, ND	ND	14
Others:							
Ethylbenzene	67	60	71	1	ND, ND	4	32
Acetone	235	229	409	130	ND, 4	108	83
Styrene	39,700+	9,200	21,200	1	ND, 1	4	12,000
Xylenes	428	202	458	2	ND, 3	4	186
Freon 113	38	74	27	15	ND, 2	ND	16
C_3-alkylbenzene	1,700	2,810	873	ND	ND	ND	930

[a] Total amount collected in both trap A (Tenax) and trap B (Tenax/charcoal)

[b] Emissions are blank corrected using the highest background level in either the field, trip, or laboratory blanks

ND -- Not detected, detection limit = 1 ng/trap significantly higher, one order of magnitude or greater, than emissions measured during either test 2 or test 3. Compounds which exceeded 100 μg/s for some measurements were benzene, toluene, carbon tetrachloride, xylenes, and Freon 113. Among these carbon tetrachloride was the only POHC not detected in the waste fuel.

Kiln operation during test 1 was characterized by several waste flow problems and generally unsteady combustion, which led to several interruptions in the sampling program. Also during run 1, the waste fuel was excessively preheated, to about 71°C (160°F), leading to flashing in the feed line to the burner and possibly some loss in atomization efficiency. Subsequent to this initial VOST test run, the waste fuel temperature was reduced to levels of about 49°C (120°F). It should also be noted that on the day prior to test 1, repairs were made to the baghouse internals and baghouse inlet ducting using a resin (with MEK hardner) rinsed with acetone. It is not known whether these repairs had a direct effect on the generally higher emissions measured during the initial test 1.

Kiln operation during tests 2 and 3 was generally steadier, with no test interruption due to unsteady combustion conditions. Test average benzene and toluene emissions were again higher than any other POHC by about one order of magnitude. Emission rates of carbon tetrachloride measured at about 20 μg/s for test 2 and 4 μg/s for test 3, a significant reduction compared to test 1 results. Emissions of Freon 113 were also lower during these two tests, 16 to 26 μg/s compared with 143 μg/s for test 1. The ratio of Freon 113 emissions to total POHC emissions remained fairly constant throughout these tests, about 4 percent during tests 2 and 3 compared to 5 percent for test 1.

Emissions of styrene were significantly higher during these two tests, 8.5 to 12 mg/s compared with only 85 μg/s for test 1. Also emissions of acetone and C_3-alkylbenzene were higher during these two tests. Xylene emissions were on the same order of magnitude throughout the site I test program.

Table 27 summarizes emissions of detected semivolatile and nonvolatile organics. Emissions included the waste fuel detected POHC's naphthalene and phthalates in the range of about 10 to 43 μg/s, site average data. Other RCRA Appendix VIII semivolatile organics detected included phenol, 2,6-dinitrotoluene and 2-chlorophenol in the range of about 8 to 50 μg/s. Slightly higher emissions were detected during tests 2 and 3 for which lower volatile organic emissions were measured.

5.2.2 POHC DRE's

Tables 28 through 34 summarize the DRE results for POHC's detected in the waste fuel at site I. The following paragraphs highlight the major results and identifiable trends for specific POHC's.

TABLE 27. SEMIVOLATILE ORGANIC EMISSIONS -- SITE I

Compound	Concentration[a], µg				Emissions rate[b] (µg/s)	
	Test 1 Sample	Test 2 Sample	Test 3 Sample	Blank	Range	Site Average
RCRA Appendix VIII:						
Phenol	21	20	76	1	19-79	52
Naphthalene	5	7	26	4	2.9-23	9.6
Dimethylphthalate	11	43	32	ND	32-43	36
2,6-dinitrotoluene	6	6	ND	ND	0-17	7.7
Dibutyl phthalate	36	13	22	3	13-95	43
2-chlorophenol	ND	ND	32	ND	0-35	12
Bis(2-chlorohexyl)phthalate	25	6	22	ND	6-72	34
Others:						
2-nitrophenol	6	16	11	ND	12-17	15
2-methylnaphthalene	15	67	ND	ND	0-67	37
Phenanthrene	10	16	14	ND	15-29	20
Benzyl alcohol	ND	12	54	ND	0-57	23

[a] Total semivolatile organics in the sample

[b] Emissions are blank corrected

TABLE 28. SUMMARY OF 1,1,1-TRICHLOROETHANE DRE's -- SITE I

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	78	34	99.96	
	2	78	89	99.88	
	3	74	49	99.93	99.92
2	1	81	38	99.95	
	2	81	59	99.93	
	3	79	18	99.98	99.95
3	1	79	<0.5	>99.9994	
	2	79	<0.5	>99.9994	
	3	80	28	99.96	99.988
Mass average results		79	35	99.95	

TABLE 29. *SUMMARY OF TRICHLOROETHYLENE DRE'S -- SITE I*

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	8.2	19	99.77	
	2	8.2	19	99.77	
	3	7.8	5.1	99.93	99.8
2	1	8.5	<0.5	>99.994	
	2	8.4	<0.5	>99.994	
	3	8.2	<0.5	>99.994	>99.994
3	1	7.1	<0.5	>99.993	
	2	7.1	<0.5	>99.993	
	3	7.2	<0.5	>99.993	>99.993
Mass average results		7.8	5.1	99.93	

TABLE 30. SUMMARY OF BENZENE DRE'S -- SITE I -

Test No.	Run No.	Firing rate (mg/s)	Emission rate (µg/s)	DRE (%)	Test average DRE (%)
1	1	8.0	3,800	52.5	
	2	8.0	160	98.	
	3	7.6	170	97.8	82.5
2	1	13.5	220	98.4	
	2	13.3	111	99.2	
	3	13.0	243	98.1	98.5
3	1	10.3	110	98.9	
	2	10.3	135	98.7	
	3	10.4	122	98.8	98.8
Mass average results		10.5	563	94.6	

TABLE 31. SUMMARY OF TETRACHLOROETHYLENE DRE'S -- SITE I

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	31.6	77	99.7	
	2	31.6	40	99.87	
	3	30.1	6.6	99.98	99.87
2	1	35.2	10	99.97	
	2	34.7	5.4	99.98	
	3	34.1	1.5	99.995	99.98
3	1	27.1	3.0	99.988	
	2	27.1	2.5	99.991	
	3	27.4	3.0	99.989	99.989
Mass average results		31	16.5	99.95	

TABLE 32. SUMMARY OF TOLUENE DRE'S -- SITE I -

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test Average DRE (%)
1	1	199	1,250	99.4	
	2	199	288	99.8	
	3	189	206	99.89	99.7
2	1	215	248	99.88	
	2	212	170	99.92	
	3	209	215	99.89	99.90
3	1	184	200	99.89	
	2	184	211	99.88	
	3	187	179	99.90	99.89
Mass average results		197	330	99.8	

TABLE 33. SUMMARY OF CHLOROBENZENE DRE'S -- SITE I

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	3	26	99.1	
	2	3	16	99.5	
	3	2.9	11	99.6	99.4
2	1	2.6	17	99.3	
	2	2.6	13	99.5	
	3	2.5	21	99.2	99.3
3	1	2.5	15	99.4	
	2	2.5	21	99.2	
	3	2.5	18	99.3	99.3
Mass average results		2.7	17	99.3	

TABLE 34. SUMMARY OF METHYL ETHYL KETONE (MEK) DRE'S -- SITE I

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	84	1.8	99.998	
	2	84	5.1	99.994	
	3	80	176	99.8	99.93
2	1	72	76	99.89	
	2	71	10	99.98	
	3	70	20	99.97	99.95
3	1	89	39	99.96	
	2	89	13	99.98	
	3	90	11	99.987	99.98
Mass average results		81	39.1	99.95	

1,1,1-Trichloroethane (1,1,1-TCA, Table 28)

DRE's for 1,1,1-TCA ranged from 99.88 to greater than 99.9994 percent for all measurements performed. Test 1 DRE's averaged 99.92 percent, rising slightly during test 2, at 99.95 percent; and test 3, at 99.988 percent. However in all tests, DRE's were lower than the four nine destruction level of 99.99 percent. Therefore, lower destruction of 1,1,1-TCA coincided with the less efficient, or stable, combustion of test 1. Site average DRE was 99.95 percent.

Trichloroethylene (TCE, Table 29)

DRE for TCE ranged from 99.77 percent during test 1 to greater than 99.994 percent during either test 2 or 3. Again, lower DRE's were recorded for test 1 as in the case of 1,1,1-TCA. Mass average DRE for this compound averaged 99.93 percent, the result of poor destruction measured during test 1.

Benzene (Table 30)

Because of the extremely high benzene emissions, DRE's for this compound were very low, ranging from about 50 percent to only about 99 percent. Test 1 DRE's averaged only about 83 percent. The results for test 2 and 3 were similar at about 98 percent. Apart from test 1, run 1, benzene emissions were relatively constant between 110 and 240 µg/s. Therefore, these emissions do not seem to indicate a trend similar to that of other organic emissions. This may be due in part to the contribution of benzene as a PIC. Site average benzene DRE was about 95 percent.

Tetrachloroethylene (PCE, Table 31)

PCE firing rate ranged from about 27 to 35 mg/s with emission rates measured in the range of 1.5 to 77 µg/s. Corresponding DRE's ranged from about 99.7 to 99.995 percent. Again, test 1 results indicate lower destruction. In fact, there seems to be a general increase in DRE with time coinciding with improved kiln operation starting with the second and third measurements of test 1 and continuing with the remainder of the tests. The overall DRE for PCE was calculated to be 99.95 percent, comparable to TCE and 1,1,1-TCA results.

Toluene (Table 32)

The trend in toluene emissions is quite comparable to that observed for benzene. With the exception of test 1, run 1 toluene emissions ranged from about 170 to 290 µg/s. Nearly a factor of 10 increase in toluene emissions was recorded for the first measurement. DRE's ranged from 99.4 percent during this first flue gas measurement to 99.92 percent during the second test. Toluene is also a known byproduct of fuel combustion. Its contribution as a PIC to these emissions is not identifiable from the data available. Mass average DRE for toluene was calculated to be 99.8 percent.

Chlorobenzene (Table 33)

The firing rate of chlorobenzene was the lowest of any of the POHC's at this site ranging from only 2.5 to 3 mg/s. The concentration of chlorobenzene in the waste fuel was only 11 to 14 mg/ml. Emissions were comparable between tests and individual measurements made. Therefore, the DRE's were also comparable, ranging from about 99.1 to 99.6 percent. With chlorobenzene there is no discernable trend of lower DRE's during test 1 as with the other POHC's.

Methyl Ethyl Ketone (MEK, Table 34)

The firing rate of MEK ranged from about 70 to 90 mg/s, comparable to that of 1,1,1-TCA. DRE's ranged from about 99.8 to 99.994 percent, both measured during test 1. The lowest DRE's were recorded during the last measurement of test 1. This seems to contradict other test data for TCE, benzene, PCE, toluene, and chlorobenzene which indicate lowest DRE's for runs 1 of test 1. Site average DRE for MEK was calculated at 99.95 percent.

Other DRE Results

Tables 35 through 40 summarize the calculated DRE's for other major volatile organics detected in the waste fuel at site I. DRE's for Freon 113, the surrogate compound added to the waste fuel, ranged from 99.98 to 99.9995 percent with a total mass average of 99.995 percent. Lowest DRE's were obtained for test 1, run 1 as is the case for most other volatile POHC's. DRE's for Freon 113 were generally higher than any of the volatile POHC's.

DRE results for other major organics (ethylbenzene, acetone, styrene, xylene, and C_3-alkylbenzene) indicate efficiencies lower than 99.99 percent in almost all measurements and test conditions. Lower DRE's for test 1 were not the case for these compounds. Results for styrene show lowest DRE's, especially during tests 2 and 3 for which the flue gas emission rate actually exceeded the firing rate.

Summary of DRE's

Table 41 summarizes the DRE results for volatile POHC's. Both the range and the mass average values for site I test measurements are indicated. Lowest mass average DRE's in the range below 99.9 percent were obtained for benzene, chlorobenzene, and toluene in that order. DRE's in the range of 99.90 to 99.990 percent were measured for TCE, 1,1,1-TCA, PCE, and MEK with almost equal mass average DRE's of 99.95 percent. Destruction for Freon 113 averaged one order of magnitude increase in efficiency. This compound was added to the waste fuel to evaluate its relative destruction compared to other volatile POHC's.

Overall, site I operation resulted in relatively low DRE's, often below the current level of 99.99 percent promulgated for hazardous waste incinerators under RCRA. These results are not entirely unexpected because the estimated process temperatures in the kiln were relatively low, 590° to

TABLE 35. SUMMARY OF FREON 113 DRE'S -- SITE I -

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	1,280	257	99.98	
	2	1,280	125	99.990	
	3	1,220	47	99.996	99.988
2	1	1,400	20	99.9986	
	2	1,380	39	99.997	
	3	1,360	19	99.9986	99.998
3	1	1,370	12	99.9991	
	2	1,370	30	99.998	
	3	1,390	6.2	99.9995	99.998
Mass average results		1,340	62	99.995	

TABLE 36. SUMMARY OF ETHYLBENZENE DRE'S -- SITE I

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	112	174	99.8	
	2	112	27	99.97	
	3	107	27	99.9	99.93
2	1	122	59	99.95	
	2	120	27	99.98	
	3	118	44	99.96	99.96
3	1	107	34	99.97	
	2	107	30	99.97	
	3	108	37	99.96	99.97
Mass average results		112	51	99.95	

TABLE 37. SUMMARY OF ACETONE DRE'S -- SITE I

Test No.	Run No.	Firing rate (mg/s)	Emission rate (µg/s)	DRE (%)	Test average DRE (%)
1	1	1,093	<0.5	>99.9999	
	2	1,093	<0.5	>99.9999	
	3	1,040	160	99.98	99.995
2	1	940	250	99.97	
	2	928	72	99.992	
	3	911	72	99.992	99.98
3	1	1,104	54	99.995	
	2	1,104	51	99.995	
	3	1,120	140	99.987	99.993
Mass average results		1,037	89	99.991	

TABLE 38. SUMMARY OF STYRENE DRE'S -- SITE I -

Test No.	Run No.	Firing rate (mg/s)	Emission rate (µg/s)	DRE (%)	Test average DRE (%)
1	1	12	123	98.97	
	2	12	69	99.4	
	3	11.5	64	99.4	99.3
2	1	9.2	24,000	N/A	
	2	9.1	970	89.3	
	3	8.9	435	95.1	N/A
3	1	8.5	>21,000	N/A	
	2	8.5	4,700	44.7	
	3	8.6	11,000	N/A	N/A
Mass average results		9.8	6,929	29.3	

NA -- Not applicable, negative DRE.

TABLE 39. SUMMARY OF XYLENE DRE'S -- SITE I

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	476	570	99.88	
	2	476	110	99.98	
	3	452	108	99.98	99.94
2	1	517	180	99.97	
	2	510	134	99.97	
	3	501	180	99.96	99.97
3	1	467	220	99.95	
	2	467	100	99.98	
	3	474	235	99.95	99.96
Mass average results		482	204	99.96	

TABLE 40. SUMMARY OF C_3-ALKYLBENZENE DRE'S -- SITE I

Test No.	Run No.	Firing rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test Average DRE (%)
1	1	71	<0.5	>99.9993	
	2	71	<0.5	>99.9993	
	3	68	68	99.90	99.97
2	1	65	385	99.4	
	2	64	180	99.7	
	3	63	96	99.8	99.6
3	1	38	880	97.7	
	2	38	1,450	96.2	
	3	38	450	98.8	97.6
Mass average results		57	389	99.3	

TABLE 41. SUMMARY OF VOLATILE POHC DRE'S -- SITE I

Compound	Firing rate (mg/s)	Emission rate (μg/s)	Test average[b] DRE, (%)
1,1,1-trichloroethane	74-81 (79)	<0.5-89 (35)	99.88-99.98 (99.95)
Trichloroethylene	7.1-8.5 (7.8)	<0.5-19 (5.1)	99.8-99.994 (99.93)
Benzene	7.6-13.5 (10.5)	110-3,800 (563)	82.5-98.5 (94.6)
Tetrachloroethylene	27.1-35.2 (31)	1.5-77 (16.5)	99.87-99.989 (99.95)
Toluene	184-215 (197)	170-1,250 (330)	99.7-99.90 (99.8)
Chlorobenzene	2.5-3.0 (2.7)	11-26 (17)	99.3-99.4 (99.3)
2-butanone (MEK)	70-90 (81)	1.8-176 (39.1)	99.93-99.98 (99.95)
1,1,2-trichloro-2,2,1-trifluoroethane (Freon 113)[a]	1,220-1,400 (1,340)	6.2-257 (62)	99.988-99.998 (99.995)

[a] Not a RCRA Appendix VIII compound. Freon 113 was added to the fuel feed for these performance tests.

[b] "Test average" represents an average of three runs obtained each test day. Number in parentheses is the average of all DRE measurements.

650°C (1,100 to 1,200°F). Although the gas residence time was estimated to be in excess of 2 sec, this low gas temperature may have been the principal cause of low POHC DRE's. During test 1, the kiln was operating under unsteady combustion conditions. Lower DRE's were measured during this test for several volatile POHC's possibly indicating a direct effect of kiln operation on POHC destruction at test operating temperatures.

Table 42 summarizes the DRE results for semivolatile organics at site I. DRE's were generally below the 99.990 percent level except for naphthalene.

5.2.3 PIC Emissions

Table 43 lists the emission rates of volatile organics detected in the flue gas of the site I kiln but not present in the waste fuel. These organics were attributed to products of incomplete combustion (PIC's) because they were not directly contributed by the waste fuel. Total PIC emissions were highest during test 1, 670 µg/s, decreasing to 150 µg/s for tests 2 and 3. Therefore, it can be stated that higher PIC emissions generally accompanied higher POHC breakthrough emissions or lower POHC DRE's for site I. The ratio of total PIC's to total POHC breakthrough ranged from about 15 to 30 percent on a test average basis. For all measurements taken, PIC's/POHC's emission ratio was 25 percent.

5.3 SITE II RESULTS

Flue gas sampling for organic emissions of site II included measurements for volatile organic compounds using VOST. The sampling and analysis protocols for VOST at site II was similar to test for site I. That is, three separate measurements for volatile organics were made for each of the four tests at this site and field, trip, and laboratory blanks were prepared to correct sample results for contamination levels associated with each of these activities. The following sections present the emission results (Section 6.3.1), the corresponding POHC DRE's (Section 5.3.2), and emission of identifiable PIC's (Section 5.3.3).

5.3.1 Emission Results

Tables 44 through 47 summarize the volatile organic emission results for each of the four tests performed at site II. Severe contamination of the trip blank VOST trap samples with methylene chloride (5,580 µg) occurred at this site. As a result emissions of methylene chloride were considered nil, although the concentration of this compound in the flue gas samples was significant. Other volatile organics detected in the blank samples in concentrations exceeding 100 µg were chloromethane (83 to 186 ng) and 1,1,1-trichloroethane (30 to 287 ng).

Volatile POHC's detected in the site II waste fuel having concentrations exceeding 500 ppm by weight on the average for the four tests were toluene (40,000 ppm); MEK (15,000 ppm); methylene chloride (5,100 ppm); PCE (3,100 ppm); 1,1,1-TCA (2,000 ppm); and TCE (660 ppm). Toluene emissions

TABLE 42. SUMMARY OF DRE's FOR SEMIVOLATILE ORGANICS -- SITE I

Compound	Firing rate (mg/s)	Emission rate (μg/s)	DRE range (%)	Average DRE (%)
RCRA Appendix VIII				
Naphthalene	148-183 (168)[a]	2.9-23 (9.6)[a]	99.987- 99.998	99.994
Dibutylphthalate	36.9-135 (79.5)	13-95 (43)	99.74- 99.985	99.946
Bis(2-ethylhexyl)phthalate	ND-59.1 (19.7)	6-72 (34)	--	99.96
Others				
2-methylnaphthalene	125-162 (148)	0-67 (37)	99.96- >99.9997	99.97

[a] Numbers in parentheses are arithmetic average of three tests.

ND -- Not detected in the fuel feed.

TABLE 43. VOLATILE PIC EMISSIONS -- SITE I

Compound (POHC's)	Concentration (μg/s)			
	Test 1	Test 2	Test 3	Site average
Carbon tetrachloride	128-930 (494)	3.4-40 (20)	3.6-4.6 (4.1)	173
Chloromethane	--	22-115 (67)[a]	0-70 (24)	30
Bromomethane	0-13 (7.7)	7.9-17 (11)	0-8.0 (5.2)	8.0
Vinylchloride	13-93 (44)	13-33 (21)	13-22 (18)	28
Dichloromethane	22-133 (72)	0-52 (17)	--	30
1,1-dichloroethane	31-102 (55)	--	--	18
Chloroform	1-7.7 (3.9)	1.5-7.9 (3.6)	--	2.5
Chloroethane	--	0-12 (4.1)	--	1.4
1,2-dichloropropane	--	0-5.4 (2.8)	--	0.9
1,1,2,2-tetrachloroethane	--	0-7.9 (2.6)	--	0.9
Total PIC's	205-1,200 (670)	93-223 (150)	43-96 (51)	293
ΣPIC's/ΣPOHC's[b]	0.30	0.30	0.14	0.25

[a] Numbers in parentheses are arithmetic averages of triplicate measurements.

[b] Sum of PIC emissions divided by the sum of breakthrough volatile POHC emissions including toluene and benzene.

-- Dashes indicate blank corrected emissions in each measurement were less than the detectable level.

TABLE 44. VOLATILE ORGANIC EMISSIONS, TEST 1 -- SITE II

	Trap concentrations (A+B)[a], ng						Test average emission rate[b] (μg/s)
	Sample			Blanks			
Compound	Run 1[c]	Run 2	Run 3	Field	Trip	Lab	
RCRA Appendix VIII:							
Chloromethane		773	1,230	266	83	186	156
Bromomethane		33	33	ND	ND	ND	7.2
Vinylchloride		50	61	ND	ND	ND	12
Dichloromethane		191	129	813	5,580	118	--
1,1-dichloroethylene		30	13	ND	ND	4	4.0
Trans-1,2-dichloroethylene		12	ND	ND	ND	ND	1.4
Chloroform		65	9	ND	ND	ND	8.6
1,2-dichloroethane		10	ND	ND	ND	ND	1.2
1,1,1-trichloroethane		42	131	61	126	118	--
Carbon tetrachloride		121	10	ND	ND	ND	15.3
Trichloroethylene		19	7	ND	ND	ND	3.5
Benzene		240	160	6	ND	5	42
Tetrachloroethylene		43	21	ND	ND	ND	7.1
Toluene		111	108	7	9	12	21.3
Chlorobenzene		79	82	ND	ND	ND	17.5
Others:							
Dichlorobromoethane		14	ND	ND	ND	ND	1.7
Ethylbenzene		12	11	3	7	7	1.0
Styrene		34	22	ND	ND	6	4.9
Xylenes		44	38	7	14	12	6.0
1,1,2-trichloro-2,2,1-trifluoroethane (Freon 113)		5	3	ND	ND	ND	0.9
C_3-alkylbenzene		11	8	ND	ND	ND	2.1

[a] Total amount collected in both trap A (Tenax) and trap B (Tenax/charcoal).

[b] Emissions are blank corrected using the highest background contamination in either the field, trip, or laboratory blanks.

[c] No data available for this test run due to broken traps during absorption.

ND -- Not detected, detection limit = 2 ng/trap (A+B).

TABLE 45. VOLATILE ORGANIC EMISSIONS, TEST 2 -- SITE II

	Trap concentrations (A+B)[a], ng						
	Sample			Blanks			Test average emission rate[b] (μg/s)
Compound	Run 1	Run 2	Run 3	Field	Trip	Lab	
RCRA Appendix VIII:							
Chloromethane	3,340	5,660	2,400	64	83	186	547
Bromomethane	686	15	16	ND	ND	ND	37
Vinylchloride	172	97	97	ND	ND	ND	18.7
Dichloromethane	2,470	1,160	399	807	5,580	118	--
1,1-dichloroethylene	16	16	16	ND	ND	4	1.9
Trans-1,2-dichloroethylene	6	4	ND	ND	ND	ND	0.5
Chloroform	31	6	8	ND	ND	ND	2.3
1,1,1-trichloroethane	41	93	64	30	126	118	--
Carbon tetrachloride	20	13	4	ND	ND	ND	1.9
Trichloroethylene	10	ND	8	ND	ND	ND	0.93
Benzene	168	170	202	3	10	5	26.0
Tetrachloroethylene	20	15	7	ND	ND	ND	2.1
Toluene	155	100	140	6	9	12	18.3
Chlorobenzene	108	94	98	ND	ND	ND	15.3
Others:							
Ethylbenzene	20	9	14	ND	7	7	1.1
Styrene	10	43	25	ND	ND	ND	4.0
Xylene	37	36	55	ND	ND	ND	20
1,1,2-trichloro-2,2,1-trifluoroethane (Freon 113)	7	4	4	ND	ND	ND	0.8
C_3-alkylbenzene	9	8	11	ND	ND	ND	1.4
4-methyl-2-pentanone	70	46	7	ND	ND	ND	6.3

[a] Total amount collected in both trap A (Tenax) and trap B (Tenax/charcoal).

[b] Emissions are blank corrected using the highest background contamination in either the field, trip, or laboratory blanks.

ND -- Not detected, detection limit = 2 ng/trap (A+B).

TABLE 46. VOLATILE ORGANIC EMISSION, TEST 3 -- SITE II

	Trap concentrations (A+B)[a], ng						
	Sample			Blanks			Test average emission rate[b]
Compound	Run 1	Run 2	Run 3	Field	Trip	Lab	(µg/s)
RCRA Appendix VIII:							
Chloromethane	6,220	3,070	2,890	156	83	186	600
Bromomethane	87	31	50	ND	ND	ND	8.9
Vinylchloride	97	82	93	ND	ND	ND	14
Dichloromethane	866	213	254	204	5,580	118	--
1,1-dichloroethylene	21	18	15	6	ND	4	2.0
Trans-1,2-dichloroethylene	8	7	5	ND	ND	ND	1.0
Chloroform	78	12	9	ND	ND	ND	5.1
1,1,1-trichloroethane	93	90	68	61	126	118	--
Carbon tetrachloride	8	17	9	ND	ND	ND	1.7
Trichloroethylene	12	10	9	ND	ND	ND	1.6
Benzene	298	200	231	5	10	5	36.1
Tetrachloroethylene	14	11	10	ND	ND	ND	1.8
Toluene	1,520	184	175	4	9	12	95.3
Chlorobenzene	195	134	108	ND	ND	ND	22.6
2-butanone (MEK)	838	ND	131	ND	ND	ND	50.1
Others:							
Ethylbenzene	212	19	18	2	7	7	11.8
Styrene	96	69	63	ND	ND	6	11
Xylenes	593	69	63	ND	14	12	35.4
1,1,2-trichloro-2,2,1-trifluoroethane (Freon 113)	3	3	3	2	ND	ND	0.5
C_3-alkylbenzene	19	12	9	ND	ND	ND	2.1
4-methyl-2-pentanone	17	ND	ND	ND	ND	ND	0.87

[a] Total amount collected in both trap A (Tenax) and trap B (Tenax/charcoal).

[b] Emissions are blank corrected using the highest background contamination in either the field, trip, or laboratory blanks.

ND -- Not detected, detection limit = 2 ng/trap (A+B).

TABLE 47. VOLATILE ORGANIC EMISSIONS, TEST 4 -- SITE II

	Trap concentrations (A+B)^{a}, ng						
	Sample			Blanks			Test average emission rate^{b} µg/s
Compound	Run 1	Run 2	Run 3	Field	Trip	Lab	
RCRA Appendix VIII:							
Chloromethane	6,570	7,470	5,240	130	83	186	968
Bromomethane	52	46	58	ND	ND	ND	8.1
Vinylchloride	88	76	81	ND	ND	ND	13
Dichloromethane	290	2,930	830	115	5,580	118	--
1,1-dichloroethylene	26	19	21	ND	ND	4	2.8
Trans-1,2-dichloroethylene	6	7	8	ND	ND	ND	1.1
Chloroform	34	13	76	ND	ND	ND	6.4
1,1,1-trichloroethane	321	145	77	287	126	118	1.8
Carbon tetrachloride	18	19	10	ND	ND	ND	2.5
Trichloroethylene	10	14	10	ND	ND	ND	1.8
Benzene	241	298	170	9	10	5	35.1
Tetrachloroethylene	12	9	10	ND	ND	ND	1.7
Toluene	219	191	1,560	7	9	12	100
Chlorobenzene	157	128	101	ND	ND	ND	20
2-butanone (MEK)	96	56	975	ND	ND	ND	58
Others:							
Ethylbenzene	21	22	285	2	7	7	31
Styrene	40	48	77	ND	ND	6	7.6
Xylenes	86	84	789	11	14	12	47
1,1,2-trichloro-2,2,1-trifluoroethane (Freon 113)	16	8	14	3	ND	ND	1.5
C_3-alkylbenzene	25	17	16	ND	ND	ND	3.0
4-methyl-2-pentanone	13	14	11	ND	ND	ND	2.0

[a] Total amount collected in both trap A (Tenax) and trap B (Tenax/charcoal).

[b] Emissions are blank corrected using the highest background contamination in either the field, trip, or laboratory blanks.

ND -- Not detected, detection limit = 2 ng/trap (A+B).

during cofiring tests 1 and 2 averaged about 20 µg/s. During the waste-fuel-only firing tests, toluene emissions increased a factor of 5 to about 100 µg/s. The heat input contributed by the pulverized coal during tests 1 and 2 was about 50 percent, therefore toluene emissions increased by a factor of 512 compared to the toluene firing rate.

MEK was not detected in the flue gas samples collected during tests 1 and 2. However, average emissions during tests 3 and 4 were about 50 to 60 µg/s. PCE emissions were selectively less throughout, measuring 1.7 to 7.1 µg/s. Blank corrected emissions of 1,1,1-TCA ranged from 0 to about 2 µg/s. Most of the flue gas samples showed concentrations of 1,1,1-TCA lower than field or trip blank samples. TCE emissions were also relatively low, ranging from about 1 to 3.5 µg/s on the average.

Total detected hazardous organic emissions ranged from about 320 to 600 µg/s on the average for tests 1 and 2 (cofiring) and 840 to 1,200 µg/s for tests 3 and 4 (waste fuel firing only). The principal compound contributing the bulk of these emissions was chloromethane, ranging from about 50 to 80 percent. Other major organic emissions exceeding 10 µg/s were contributed by benzene (26 to 42 µg/s) during all four tests, toluene (18 to 100 µg/s), MEK (50 to 58 µg/s) only during tests 3 and 4, chlorobenzene and vinylchloride (12 to 23 µg/s).

Emissions of Freon 113 were very low, near the detection limit of the protocols used in most measurements. Emissions ranged from 0.5 to 1.5 µg/s. There was no trend of measured Freon 113 emissions during the waste fuel only tests. In fact, apart from chloromethane, toluene, and MEK, the operation of the kiln on waste fuel only did not result in an observable trend of increased POHC emissions with the increased firing rate of these compounds.

5.3.2 DRE Results

Tables 48 through 57 summarize the DRE's of each volatile POHC from tests 1 through 4 at site II. The tables also indicate the mass average DRE for each compound for the cofiring tests 1 and 2 and the waste fuel only tests 3 and 4. The DRE's for methylene chloride and 1,1,1-TCA generally exceeded the six nines, 99.9999 percent efficiency, throughout the test program at site II. Of course these results are due to the relatively higher blank values which resulted in blank corrected emission rates corresponding to the detection limit of the analytical protocols. Similarly, emissions of 1,2-dichloroethane were not detected in the flue gas. Corresponding DRE's for this compound exceeded 99.99 percent in all measurements. The following paragraphs highlight the major results and trends in DRE's specific to compounds and firing rates.

Carbon Tetrachloride (Table 51)

The firing rate of carbon tetrachloride during tests 1 and 2 ranged from about 12 to 17 mg/s. The DRE's for these tests ranged from 99.8 of run 2 test 1 to 99.995 for the last measurement of test 2. Kiln operation during that portion of test 1 corresponding to the VOST run 2 was not noticeably

TABLE 48. SUMMARY OF DICHLOROMETHANE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	906	<0.3	>99.99997	>99.99997
	2	934	<0.3	>99.99997	
	3	1,130	<0.3	>99.99997	
2	1	850	<0.3	>99.99996	>99.99996
	2	760	<0.3	>99.99996	
	3	850	<0.3	>99.99996	
3	1	1,570	<0.3	>99.99998	>99.99998
	2	1,510	<0.3	>99.99998	
	3	1,550	<0.3	>99.99998	
4	1	1,160	<0.3	>99.99997	>99.99998
	2	1,540	<0.3	>99.99998	
	3	1,470	<0.3	>99.99998	
Average results tests 1 and 2		905	<0.3	>99.99997	
Average results tests 3 and 4		1,467	<0.3	>99.99998	

NA -- Not available, lost sample.

TABLE 49. SUMMARY OF 1,2-DICHLOROETHANE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	26.6	NA	NA	99.996
	2	27.4	2.4	99.991	
	3	33.2	<0.3	>99.9991	
2	1	23.2	<0.3	>99.998	>99.9998
	2	20.8	<0.3	>99.998	
	3	23.2	<0.3	>99.9998	
3	1	41.0	<0.3	>99.9993	>99.9993
	2	39.7	<0.3	>99.9992	
	3	40.5	<0.3	>99.9993	
4	1	33.1	<0.3	>99.9991	>99.9993
	2	43.7	<0.3	>99.9993	
	3	41.8	<0.3	>99.9993	
Average results tests 1 and 2		25.7	<0.6	>99.998	
Average results tests 3 and 4		40.0	<0.3	>99.9993	

NA -- Not available, lost sample.

TABLE 50. SUMMARY OF 1,1,1-TRICHLOROETHANE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	329	NA	NA	99.9998
	2	339	<0.3	>99.99991	
	3	411	<1.0	99.9998	
2	1	323	<0.3	>99.9999	>99.9999
	2	289	<0.3	>99.9999	
	3	323	<0.3	>99.9999	
3	1	634	<0.3	>99.99995	>99.99995
	2	613	<0.3	>99.99995	
	3	627	<0.3	>99.99995	
4	1	480	<5.3	99.999	99.9997
	2	630	<0.3	>99.99995	
	3	605	<0.3	>99.99995	
Average results tests 1 and 2		336	<0.4	>99.9999	
Average results tests 3 and 4		599	<0.4	>99.9999	

NA -- Not available, lost sample.

TABLE 51. SUMMARY OF CARBON TETRACHLORIDE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	13.4	NA	NA	99.90
	2	13.8	28.6	99.8	
	3	16.7	2.0	99.99	
2	1	12.9	3.1	99.98	99.98
	2	11.5	1.9	99.98	
	3	12.9	0.62	99.995	
3	1	26.2	1.2	99.995	99.993
	2	25.3	2.6	99.990	
	3	25.9	1.4	99.994	
4	1	19.4	2.8	99.98	99.989
	2	25.6	3.0	99.988	
	3	24.5	1.6	99.993	
Average results tests 1 and 2		13.5	7.2	99.94	
Average results tests 3 and 4		24.5	2.1	99.991	

NA -- Not available, lost sample.

TABLE 52. SUMMARY OF TRICHLOROETHLENE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	123	NA	NA	99.998
	2	127	4.5	99.996	
	3	154	1.4	99.9991	
2	1	126	1.6	99.998	99.9992
	2	113	<0.3	>99.9997	
	3	126	1.2	99.9990	
3	1	139	1.9	99.9986	99.9988
	2	135	1.6	99.9988	
	3	138	1.4	99.9990	
4	1	173	1.6	99.9991	99.9991
	2	229	2.2	99.9990	
	3	218	1.6	99.9993	
Average results. tests 1 and 2		128	1.7	99.998	
Average results tests 3 and 4		172	1.7	99.9990	

NA -- Not available, lost sample.

TABLE 53. SUMMARY OF BENZENE DRE -- SITE II -

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	21.4	NA	NA	99.82
	2	22.0	54	99.75	
	3	26.7	30	99.88	
2	1	22.0	24.5	99.88	99.88
	2	19.7	23.6	99.88	
	3	22.0	29.8	99.86	
3	1	24.6	44.6	99.82	99.84
	2	23.8	29.5	99.87	
	3	24.3	34.3	99.85	
4	1	31.0	35.8	99.88	99.90
	2	40.9	44.6	99.89	
	3	39.1	24.8	99.93	
Average results tests 1 and 2		22.3	32.4	99.85	
Average results tests 3 and 4		30.6	35.6	99.88	

NA -- Not available, lost sample.

TABLE 54. SUMMARY OF TETRACHLOROETHYLENE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	556	NA	NA	99.998
	2	572	10	99.998	
	3	695	4.2	99.9994	
2	1	583	3.1	99.9995	99.9996
	2	522	2.2	99.9996	
	3	583	1.1	99.9998	
3	1	666	2.2	99.9997	99.9997
	2	644	1.7	99.9997	
	3	658	1.6	99.9997	
4	1	834	1.9	99.9998	99.9998
	2	1,100	1.5	99.9998	
	3	1,050	1.6	99.9998	
Average results tests 1 and 2		585	4.12	99.9993	
Average results tests 3 and 4		825	1.75	99.9998	

NA -- Not available, lost sample.

TABLE 55. SUMMARY OF TOLUENE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	8,360	NA	NA	99.9998
	2	8,600	23.4	99.9997	
	3	10,400	19.2	99.9998	
2	1	7,500	22.2	99.9997	99.9997
	2	6,700	13.0	99.9998	
	3	7,500	19.8	99.9997	
3	1	8,390	234	99.997	99.998
	2	8,110	26.7	99.9997	
	3	8,300	25.3	99.9997	
4	1	10,300	32.1	99.9997	99.9992
	2	13,700	27.8	99.9998	
	3	13,000	240	99.998	
Average results tests 1 and 2		8,177	19.52	99.9998	
Average results tests 3 and 4		10,300	97.65	99.9990	

NA -- Not available, lost sample.

TABLE 56. SUMMARY OF CHLOROBENZENE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	33.4	NA	NA	99.95
	2	34.4	19	99.94	
	3	41.7	16	99.96	
2	1	29.4	17	99.94	99.94
	2	26.3	14	99.95	
	3	29.4	15	99.95	
3	1	37.6	30	99.92	99.94
	2	36.3	21	99.94	
	3	37.1	17	99.95	
4	1	43.5	24	99.94	99.96
	2	57.5	20	99.96	
	3	54.9	17	99.97	
Average results tests 1 and 2		32.43	16.2	99.95	
Average results tests 3 and 4		44.48	21.5	99.95	

NA -- Not available, lost sample.

TABLE 57. SUMMARY OF 2-BUTANONE (MEK) DRE -- SITE H

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	2,590	NA	NA	>99.99998
	2	2,670	<0.3	>99.99998	
	3	3,230	<0.3	>99.999991	
2	1	3,140	<0.3	>99.999990	>99.999990
	2	2,800	<0.3	>99.99998	
	3	3,140	<0.3	>99.999990	
3	1	4,160	130	99.997	99.998
	2	4,030	<0.3	>99.999992	
	3	4,120	20	99.9995	
4	1	3,330	15	99.9995	99.998
	2	4,400	8.7	99.9998	
	3	4,200	150	99.996	
Average results tests 1 and 2		2,928	<0.3	>99.99998	
Average results tests 3 and 4		4,040	54	99.998	

NA -- Not available, lost sample.

different, therefore it is not clear whether any specific kiln operation may have contributed to the higher carbon tetrachloride emission during this portion of test 1. DRE's for tests 3 and 4 were higher, ranging from 99.98 to 99.995 percent with carbon tetrachloride firing rate in the range of 20 to 26 mg/s. On the average, carbon tetrachloride destruction during the cofiring tests was 99.94 percent efficient compared to 99.991 percent of the waste fuel only firing tests.

Trichloroethylene (TCE, Table 52)

DRE's for TCE were relatively constant throughout the test program at site II, at about the 99.999 percent level. Slightly lower DRE's were recorded for the test 1, run 2 measurement as in the case of carbon tetrachloride. However, no kiln operation or fuel factor could be identified as contributing to this result.

Benzene (Table 53)

DRE's for benzene were below 99.90 percent for all measurements. As indicated in Section 5.2, benzene can be attributed in part to a byproduct of combustion for most fuels, therefore emissions recorded at this site may not be entirely attributable to POHC breakthrough. Resulting DRE's are likely to be affected by the firing rate of benzene since a background benzene emission level may be present in most combustion gases. Benzene emissions at site I were in the range of about 100 to 200 µg/s except for the high emission levels during the unstable combustion conditions that occurred during the initial portion of test 1. These levels correspond to about 5 times those measured at site II, although the firing rate at site II was significantly higher.

Tetrachloroethylene (PCE, Table 54)

DRE's for PCE exceeded 99.999 percent for nearly all test measurements. Slightly higher PCE emissions and therefore lower DRE's were recorded for test 1, run 2 as in the case of carbon tetrachloride, trichloroethylene, and benzene. Slightly lower average DRE results for the cofiring tests are the result of the measurements obtained during test 1.

Toluene (Table 55)

Toluene DRE's also exceeded 99.999 percent in most cases except for portions of tests 3 and 4. No test condition or fuel factor could be identified as contributing to these lower DRE's during waste fuel firing only.

Chlorobenzene (Table 56)

Chlorobenzene together with benzene was found to have the lowest DRE's of any of the POHC's at site II. DRE's were relatively constant independent of test measurement, ranging from 99.92 to 99.97 percent. Average DRE's were the same for the cofiring and the waste fuel only tests at 99.95 percent.

Methyl Ethyl Ketone (MEK, Table 57)

DRE's for MEK was generally very high due to the high firing rates in the range of 2,600 to 4,400 mg/s and several test measurements indicating less than detectable emission rates. The pattern of MEK emissions is very similar to that of toluene in that during some portions of tests 3 and 4 higher emission rates were recorded for both these compounds. Therefore, the average DRE for MEK during waste fuel firing only was significantly lower 99.998 percent than that recorded for the cofiring tests (>99.9999 percent).

Other DRE Results

Tables 58 through 63 list calculated DRE's for other major organics detected in the waste fuels. These compounds are not listed in RCRA Appendix VIII. Results for these organics indicate DRE's comparable to those obtained for POHC's. DRE's for Freon 113 exceeded 99.9999 percent during all four tests with very little difference between each measurement. DRE's for ethylbenzene were measurably lower for the waste fuel only tests 3 and 4, 99.997 versus 99.99997 percent. DRE's for styrene and C_3-alkylbenzene also show relatively no difference between test conditions. Styrene DRE's were lower at 99.998 percent compared to 99.9996 percent for C_3-alkylbenzene. Xylenes were destroyed at levels exceeding 99.999 percent in all measurements. Greater DRE's were recorded for the cofiring tests. This result is due to high xylene emissions measured during the same test measurements for which higher carbon tetrachloride, trichloroethylene, and benzene were also measured. DRE's for 4-methyl-2-pentanone also exceeded 99.999 percent in all tests.

Summary of DRE's

Table 64 summarizes the DRE's for all volatile POHC's at site II for cofiring and waste fuel only tests. The data indicate that with the exception of benzene, chlorobenzene, and carbon tetrachloride (tests 1 and 2 only) the DRE's were in excess of 99.99 percent and in most cases exceeded 99.999 percent. DRE's for benzene were the lowest independent of fuel firing conditions followed by carbon tetrachloride at 99.94 percent during the cofiring tests and chlorobenzene at 99.95 percent during both fuel firing conditions tested.

It is interesting to point out that these low DRE's resulted for those POHC's having significantly lower firing rate compared to other volatile POHC's in the waste fuel. The firing rate for these three compounds ranged from about 12 to 58 mg/s compared to most other compounds, except 1,2-dichloroethylene, having firing rates in the range of about 110 to 14,000 mg/s. This may indicate the importance of background emission levels (PIC's) in the flue gas attributed to byproducts of fuel combustion as well as the level of background contamination and uncertainty associated with low-level detection of volatile organics.

In general, high DRE's for site II are attributed primarily to higher kiln process temperatures in the range of 1,120° to 1,180°C (2,050° to

TABLE 58. SUMMARY OF FREON 113 DRE -- SITE II -

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	1,330	NA	NA	99.99994
	2	1,370	1.2	99.99991	
	3	1,660	0.6	99.99996	
2	1	1,510	1.1	99.99993	99.99995
	2	1,350	0.59	99.99996	
	3	1,510	0.62	99.99996	
3	1	2,810	0.5	99.99998	99.99998
	2	2,710	0.5	99.99998	
	3	2,780	0.5	99.99998	
4	1	2,400	2.0	99.99992	99.99994
	2	2,800	0.8	99.99997	
	3	2,680	1.7	99.99994	
Average results tests 1 and 2		1,455	0.82	99.99994	
Average results tests 3 and 4		2,697	1.0	99.99996	

NA -- Not available, lost sample.

TABLE 59. SUMMARY OF ETHYLBENZENE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	3,765	NA	NA	99.99998
	2	3,887	1.2	99.99997	
	3	4,706	0.8	99.99998	
2	1	3,890	2.0	99.99995	99.99997
	2	3,704	0.3	99.999992	
	3	3,890	1.1	99.99997	
3	1	4,693	31.8	99.9993	99.9997
	2	4,537	1.9	99.99996	
	3	4,646	1.7	99.99996	
4	1	17,010	2.2	99.99998	99.9997
	2	7,484	2.3	99.99997	
	3	7,157	89	99.998	
Average results tests 1 and 2		3,974	1.08	99.99997	
Average results tests 3 and 4		7,588	21.5	99.9997	

NA -- Not available, lost sample.

TABLE 60. SUMMARY OF STYRENE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (µg/s)	DRE (%)	Test average DRE (%)
1	1	252	NA	NA	99.998
	2	260	6.6	99.997	
	3	315	3.2	99.998	
2	1	248	1.6	99.9993	99.998
	2	236	6.4	99.997	
	3	248	3.9	99.998	
3	1	261	14	99.995	99.996
	2	253	9.8	99.996	
	3	259	8.8	99.997	
4	1	992	5.3	99.9995	99.998
	2	436	6.5	99.998	
	3	417	11	99.997	
Average results tests 1 and 2		260	4.3	99.998	
Average results tests 3 and 4		436	9.2	99.998	

NA -- Not available, lost sample.

TABLE 61. SUMMARY OF XYLENES DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	14,651	NA	NA	99.99996
	2	15,126	7.1	99.99995	
	3	18,314	4.8	99.99997	
2	1	13,832	5.7	99.99996	99.99995
	2	13,173	5.3	99.99996	
	3	13,832	8.5	99.99994	
3	1	16,285	90	99.9994	99.9998
	2	15,743	8.5	99.99995	
	3	16,123	7.6	99.99995	
4	1	59,606	11	99.99998	99.9998
	2	26,226	11	99.99996	
	3	25,079	120	99.9995	
Average results tests 1 and 2		14,821	6.3	99.99996	
Average results tests 3 and 4		26,510	41.3	99.9998	

NA -- Not available, lost sample.

TABLE 62. SUMMARY OF C_3-ALKYLBENZENE DRE -- SITE LI

Test No.	Run No.	Input rate (mg/s)	Emission rate (µg/s)	DRE (%)	Test average DRE (%)
1	1	383	NA	NA	99.9995
	2	396	2.6	99.9993	
	3	479	1.6	99.9997	
2	1	367	1.4	99.9996	99.9996
	2	350	1.2	99.9996	
	3	367	1.7	99.9995	
3	1	425	3.0	99.9993	99.9995
	2	411	1.9	99.9995	
	3	421	1.4	99.9997	
4	1	1,602	3.9	99.9997	99.9997
	2	705	2.6	99.9996	
	3	674	2.5	99.9996	
Average results tests 1 and 2		390	1.7	99.9996	
Average results tests 3 and 4		706	2.55	99.9996	

NA -- Not available, lost sample.

TABLE 63. SUMMARY OF 4-METHYL-2-PENTANONE DRE -- SITE II

Test No.	Run No.	Input rate (mg/s)	Emission rate (μg/s)	DRE (%)	Test average DRE (%)
1	1	2,068	NA	NA	NA
	2	2,135	NA	NA	
	3	2,585	NA	NA	
2	1	2,441	11	99.9995	99.9997
	2	2,325	6.8	99.9997	
	3	2,441	1.1	99.99995	
3	1	2,325	2.6	99.9998	99.9998
	2	2,247	ND	NA	
	3	2,301	ND	NA	
4	1	8,718	2.0	99.99998	99.99996
	2	3,836	2.2	99.99994	
	3	3,668	1.7	99.99995	
Average results tests 1 and 2		2,332	6.3	99.9997	
Average results tests 3 and 4		3,850	2.1	99.99994	

NA -- Not available, lost sample.

TABLE 64. POHC DRE SUMMARY -- SITE II

Volatile POHC	Firing rate (mg/s)	Emission rate (µg/s)	Test Average DRE (%)[a]	
			Tests 1 and 2	Tests 3 and 4
Dichloromethane	850 to 1,570 (1,190)	<0.3	>99.99996	>99.99998
1,2-dichloroethane	20.8 to 43.7 (32.9)	<0.3 to 2.4 (<0.3)	99.91 to >99.9998 (>99.998)	>99.9993
1,1,1-trichloroethane	289 to 634 (468)	<0.3 to 5.3 (<0.4)	99.9998 to >99.9999 (>99.9999)	>99.9999
Carbon tetrachloride	11.5 to 26.2 (19.0)	0.62 to 28.6 (4.7)	99.8 to 99.995 (99.94)	99.98 to 99.994 (99.991)
Trichloroethylene	113 to 229 (150)	<0.3 to 4.5 (1.7)	99.996 to >99.9991 (99.998)	99.998 to >99.9993 (99.9990)
Benzene	19.7 to 40.9 (26.4)	23.6 to 44.6 (34.0)	99.75 to 99.88 (99.85)	99.82 to 99.93 (99.88)
Tetrachloroethylene	522 to 1,100 (705)	1.0 to 10 (2.8)	99.998 to 99.9998 (99.9993)	99.9997 to 99.9998 (99.9998)
Toluene	6,700 to 13,700 (9,255)	13.0 to 240 (62.14)	99.9997 to 99.9998 (99.9998)	99.997 to 99.9998 (99.9990)
Chlorobenzene	26.3 to 57.5 (38.4)	14 to 30 (19.1)	99.94 to 99.96 (99.95)	99.92 to 99.97 (99.95)
2-butanone (MEK)	2,590 to 4,400 (3,484)	<0.3 to 150 (29.6)	>99.99998 to 99.999991 (>99.99998)	99.996 to >99.999992 (99.998)
1,1,2-trichloro-2,2,1-trifluoroethane (Freon 113)[b]	1,330 to 2,810 (2,076)	0.5 to 2.0 (0.84)	99.99991 to 99.99996 (99.99994)	99.99992 to 99.99998 (99.99996)

[a] "Test average" represents the average of three runs obtained each test day. Number in parentheses is the average of all DRE measurements during cofiring (tests 1 and 2) and waste-fuel-firing-only (tests 3 and 4), respectively.

[b] Not a RCRA Appendix VIII compound. Freon 113 was added to the waste fuel feed for these performance tests.

2,150°F) for the aggregate kiln compared to the 590° to 650°C (1,100° to 1,200°F) for the kiln dryer of site I. However, unstable combustion conditions that occurred during the initial portion of the test program at site I may have also contributed to the lower volatile POHC DRE's at this site.

5.3.3 PIC Emissions

Table 65 summarizes emission rates of RCRA-listed volatile organics not present in the waste fuel burned in the site II aggregate kiln. As indicated, chloromethane accounts for the bulk (95 percent) of the PIC emissions. Other detected PIC's included vinylchloride and bromomethane with emission rates of about 7 to 37 µg/s and chloroform, 1,1-dichloroethylene and trans-1,2-dichloroethylene with emission rates typically less than 7 µg/s. Total PIC emissions were greater during the waste fuel only tests 3 and 4 which correspond to a greater POHC firing rate. The ratio of total PIC's to total POHC emissions was relatively constant ranging from only 0.76 to 0.83 compared to site I results showing ΣPIC's/ΣPOHC's in the range from 0.15 to 0.30. Site I results were associated with generally lower DRE's and therefore higher POHC's breakthrough.

5.4 RELATIVE ANALYSIS OF SITE I AND SITE II DRE RESULTS

Figure 3 illustrates the relative DRE's of major volatile POHC's for both sites I and II. Site II DRE results are shown according to the cofiring and waste fuel only test conditions investigated. The horizontal dashed lines on the bars indicate DRE's exceeding the value shown in the figure. The following paragraphs summarize the conclusions to be drawn from these data.

With the exception of Freon 113, all volatile POHC's incinerated in the site I rotary kiln dryer showed DRE's lower than 99.99 percent efficiency. These results are attributed primarily to the low kiln process temperature barely exceeding 600°C (1,100°F). Nonflame destruction studies at the laboratory scale and developed kinetics data indicate that most volatile POHC's investigated in this study require process temperatures in excess of 600°C (1,100°F) for 2 sec. Although the estimated gas residence time was sufficient in the site I kiln, temperatures may have been too low for efficient thermal destruction.

It is likely that because of the relatively rapid rotation of the kiln and the high clay throughput, the flame is quenched by the clay and moisture within the kiln. Unstable combustion conditions experienced during the initial measurements of site I can also cause lower thermal destruction of agencies in the waste fuel. This lowering of DRE's may have been enhanced by the overall low temperature environment of the kiln. The high DRE for Freon 113 may indicate that the compound is not an appropriate surrogate for estimating the DRE of most volatile organics investigated in this study.

For site II, POHC DRE's generally exceeded the 99.99 percent level with the exception of benzene, carbon tetrachloride, and chlorobenzene. These

TABLE 65. VOLATILE PIC EMISSIONS -- SITE II

	Concentration (μg/s)		
Compound (POHC's)	Cofiring (tests 1 and 2)	Waste fuel only (tests 3 and 4)	Site average
Chloromethane	156-547 (350)[a]	600-968 (780)	570
Bromomethane	7.2-37 (22)	8.1-8.9 (8.4)	15
Vinylchloride	12-19 (16)	13-14 (14)	17
1,1-dichloroethylene	4.0-1.9 (3.0)	2.0-2.8 (2.4)	2.7
Trans-1,2-dichloroethylene	1.4-0.5 (1.0)	1.0-1.1 (1.0)	1.0
Chloroform	8.6-2.5 (5.5)	5.1-6.4 (5.8)	5.7
Total PIC's	190-610 (400)	630-1,000 (810)	600
ΣPIC's/ΣPOHC's[b]	0.64-0.91 (0.83)	0.70-0.83 (0.76)	0.80

[a] Each entry is the arithmetic average of three measurements for each test. Number in parentheses is the average for the two tests indicated.

[b] Sum of PIC emissions divided by the sum of breakthrough volatile POHC emissions including benzene and toluene.

-- Dashes indicate blank corrected emission in each measurement were less than the detectable levels.

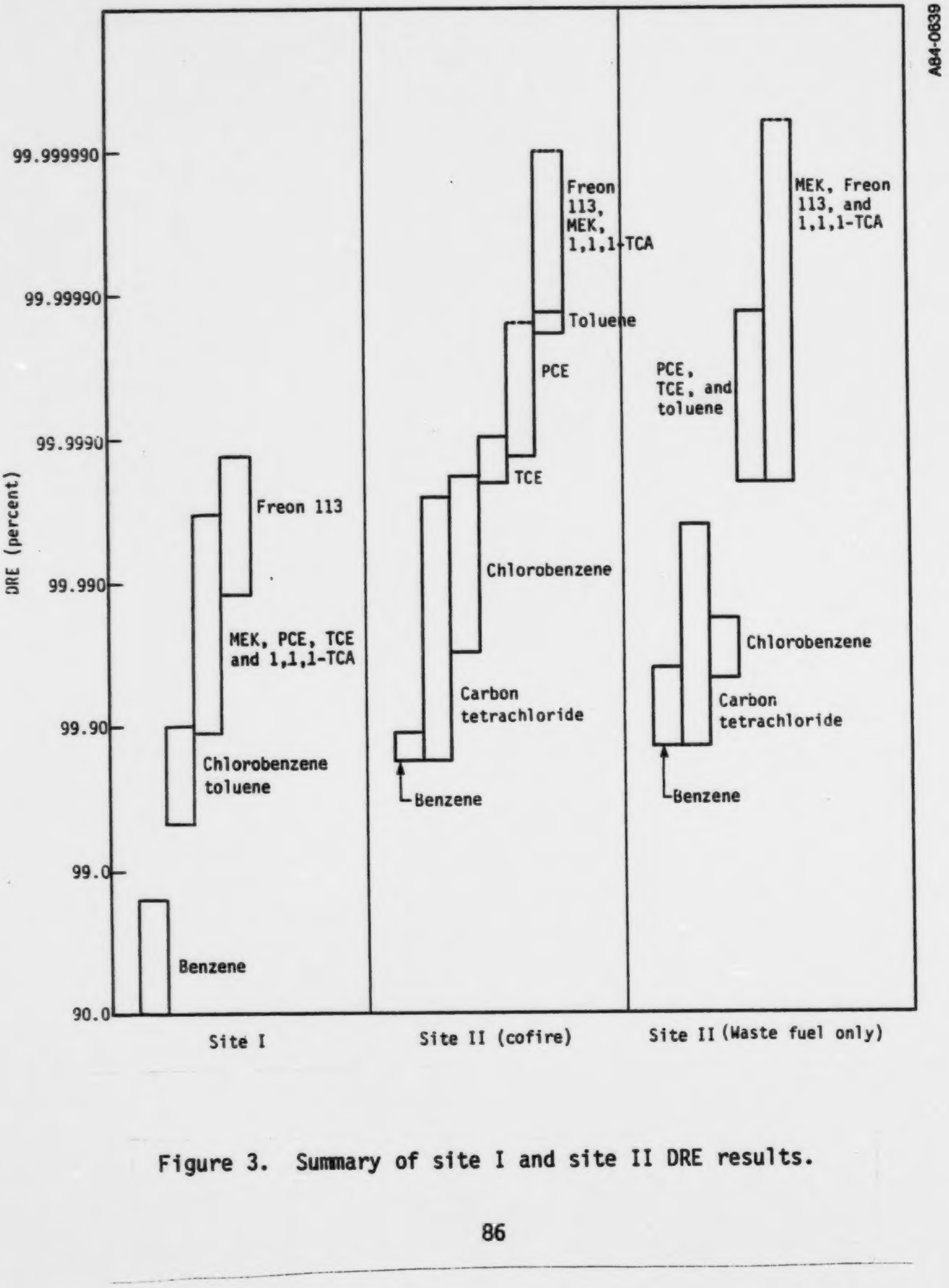


Figure 3. Summary of site I and site II DRE results.

compounds were present in the waste fuel at very low concentrations compared to other volatile POHC's. DRE's for benzene were lowest as is the case for site I test data. High DRE's were obtained for PCE, TCE, toluene, MEK, 1,1,1-TCA, and Freon 113. Again, DRE's for Freon 113 were at higher levels compared to other POHC's. High kiln temperatures for site II are considered responsible for greater POHC thermal destruction.

SECTION 6

TRACE ELEMENT EMISSION RESULTS

Trace element analyses of fuels burned and flue gas emissions were performed at both test sites. The laboratory analyses were limited to the thirteen listed priority pollutant elements. Analytical results of flue gas samples were based on the filter particulate captured by the modified EPA Method 5 sample train for site I and the filter particulate of the EPA Method 5 train for site II.

Tables 66 through 68 summarizes the analytical results of trace metals for site I. Both input mass rates and flue gas emission rates of each element detected in the samples is shown. Lead, copper, and zinc had the highest waste fuel concentration ranging from about 400 to nearly 700 ppm. The corresponding kiln input rates of these metals were on the order of 84 to 145 mg/s. Other metals detected in the waste fuel were cadmium, chromium, and nickel in concentrations ranging from about 1 to 5 ppm corresponding to mass rates in the range of about 200 to 1,000 µg/s.

Lead and zinc were the two metals found to have highest concentrations in the flue gas samples. Emissions ranged between 60 to 130 µg/s with no statistically significant difference between the three tests. These emission rates generally correspond to less than 0.1 percent of the total input rate. Therefore, the bulk of these metals were absorbed by the clay product or collected in the baghouse. No laboratory analyses were performed on these streams. Emissions of other trace metals generally ranged from about 5 to 35 µg/s, corresponding to about 1 to 13 percent of the total input rate.

Tables 69 through 72 summarize the trace metal results for site II. For tests 1 and 2 the fuel burned in the aggregate kiln was a combination of pulverized coal and waste fuel. Trace element analyses were performed on both fuels. Fewer elements were sought in the coal analyses. Lead was the element having the highest concentration with the bulk contributed by the waste fuel. Its input rate ranged from about 160 to 170 µg/s for the cofired tests. Lead input rate increased above 250 mg/s during tests 3 and 4 because of the increase in waste fuel firing rate.

Other trace elements having concentrations exceeding 100 ppm in the waste fuel were chromium, copper, and zinc. Kiln input rates of these elements ranged from about 20 to 45 mg/s for tests 1 and 2 and 25 to 87 mg/s for tests 3 and 4.

TABLE 66. SITE I TRACE METALS EMISSIONS -- TEST 1

Element[a]	Waste fuel concentration (ppm)	Total input rate (μg/s)	Total emission rate[b] (μg/s)	Mass balance (out/in) (percent)
Cadmium	1.1	230	<5.8	2.5
Chromium	4.8	990	29	2.9
Copper	460	95,000	32	0.03
Lead	530	109,000	66	0.06
Nickel	1.3	270	35	13
Zinc	570	120,000	130	0.11
Total	--	325,000	290	0.09

[a] Analysis was limited to priority pollutant elements. Metals listed are those that were detected in both fuels amd flue gas emission streams.

[b] Emissions are blank corrected.

TABLE 67. SITE I TRACE METALS EMISSIONS -- TEST 2

Element[a]	Waste fuel concentration (ppm)	Total input rate (μg/s)	Total emission rate[b] (μg/s)	Mass balance (out/in) (percent)
Cadmium	1.0	210	<2	<1.0
Chromium	4.0	850	10	1.2
Copper	400	84,600	92	0.11
Lead	630	133,000	70	0.05
Nickel	1.2	250	5	2.0
Silver	<1.0	<200	15	>7.5
Zinc	580	123,000	59	0.05
Total	--	342,000	250	0.07

[a] Analysis was limited to priority pollutants. Metals listed are those that were detected in both fuels and flue gas emission streams.

[b] Emissions are blank corrected.

TABLE 68. SITE I TRACE METALS EMISSIONS -- TEST 3

Element[a]	Waste fuel concentracion (ppm)	Total input rate (µg/s)	Total emission rate[b] (µg/s)	Mass balance (out/in) (percent)
Cadmium	1.0	210	<2	<1.0
Chromium	4.2	880	15	1.7
Copper	410	86,000	12	1.01
Lead	690	145,000	96	0.07
Nickel	1.3	270	8.5	3.2
Silver	<1	<200	4.8	>2.4
Zinc	570	120,000	99	0.08
Total	--	352,000	235	0.07

[a] Analysis was limited to priority pollutants. Metals listed are those that were detected in both fuels and flue gas emission streams.

[b] Emissions are blank corrected.

TABLE 69. SITE II TRACE METALS EMISSIONS -- TEST 1

Element[a]	Fuel concentration (ppm)		Total input rate (μg/s)	Total emission rate[b] (μg/s)	Mass balance (out/in) (percent)
	Coal	Wastefuel			
Antimony	NA	9.4	--	<5.4	--
Cadmium	ND	8.5	1,830	174	9.5
Chromium	ND	140	30,130	1,740	5.8
Copper	10	92	21,100	430	2.0
Lead	14	750	163,000	8,850	5.4
Mercury	NA	0.5	--	<0.5	--
Nickel	9	2.9	1,790	190	11
Zinc	25	175	40,900	1,310	3.2
Total	--	--	261,000	12,700	4.9

[a] Analysis was limited to the priority pollutant elements. Metals listed are those that were detected in both fuels and flue gas emission streams.
[b] Emissions are blank corrected.

NA -- Not analyzed.
ND -- Not detected. generally below 1 to 5 ppm.

TABLE 70. SITE II TRACE METALS EMISSIONS -- TEST 2

Element[a]	Fuel concentration (ppm) Coal	Fuel concentration (ppm) Wastefuel	Total input rate (µg/s)	Total emission rate[b] (µg/s)	Mass balance (out/in) (percent)
Antimony	NA	9.0	--	<5.7	--
Cadmium	ND	8.9	1,560	100	6.4
Chromium	ND	130	22,700	1,290	5.7
Copper	15	90	18,300	260	1.4
Lead	15	975	173,000	6,300	3.6
Mercury	NA	0.6	--	<0.6	--
Nickel	5	2.7	1,325	<14	<1.1
Zinc	6	250	44,700	690	1.5
Total	--	--	263,000	8,640	3.3

[a] Analysis was limited to the priority pollutant elements. Metals listed are those that were detected in both fuels and flue gas emission streams.

[b] Emissions are blank corrected.

NA -- Not analyzed.
ND -- Not detected, Generally below 1 to 5 ppm.

TABLE 71. SITE I TRACE METALS EMISSIONS -- TEST 3

Element[a]	Waste fuel concentration (ppm)	Total input rate (μg/s)	Total emission rate[b] (μg/s)	Mass balance (out/in) (percent)
Antimony	8.0	2,250	<5.6	<0.25
Cadmium	8.9	2,500	450	18
Chromium	105	29,500	1,400	4.8
Copper	92	25,800	1,120	4.3
Lead	900	253,000	25,000	9.9
Mercury	0.4	112	<0.6	<0.5
Nickel	2.7	760	<14	<1.8
Zinc	260	73,000	4,290	5.9
Total	--	387,000	32,300	8.3

[a] Analysis was limited to priority pollutants. Metals listed are those that were detected in both fuels and flue gas emission streams.
[b] Emissions are blank corrected.

TABLE 72. SITE I TRACE METALS EMISSIONS -- TEST 4

Element[a]	Waste fuel concentration (ppm)	Total input rate (μg/s)	Total emission rate[b] (μg/s)	Mass balance (out/in) (percent)
Antimony	9.4	2,640	<5.8	<0.22
Cadmium	9.6	2,700	440	16
Chromium	130	36,500	1,170	3.2
Copper	105	29,500	1,020	3.5
Lead	950	267,000	25,000	9.4
Mercury	0.6	170	<0.6	<0.4
Nickel	2.9	820	<14	<1.7
Zinc	310	87,000	4,570	5.3
Total	--	426,000	32,200	7.6

[a] Analysis was limited to the priority pollutant elements. Metals listed are those that were detected in both fuels and flue gas emission streams.

[b] Emissions are blank corrected.

Site II emissions were highest for lead (6.3 to 8.9 mg/s for the cofired tests) increasing to 25 mg/s for tests 3 and 4. Lead emissions accounted for 3.6 to 5.4 percent of the lead input for cofiring, increasing to 9.4 to 9.9 for waste fuel firing.

In general, the amount of trace elements in the flue gas of site II was proportionately greater than for site I. Also, the amount of metals in the flue gas during waste fuel firing of tests 3 and 4 was a greater percentage of the input rate than that for the cofiring tests. This may indicate that several elements were adsorbed on the entrained dust and collected more efficiently by the fabric filter of site I. The firing of coal introduced a larger quantity of flyash which may have also adsorbed a greater quantity of these elements, causing them to be collected more efficiently by the scrubber. Higher process temperatures for the site II kiln may also have increased the amount of elements not adsorbed in the kiln product.

SECTION 7

CONCLUSIONS

A comprehensive emission measurement program was performed on two industrial process kilns burning liquid hazardous wastes. The primary objective of the program was to evaluate the effectiveness of the two kilns in destroying hazardous wastes. Additional objectives were to measure organic byproduct and inorganic element emissions from stack gas and other waste discharge streams. Aside from differences in production processes, the two kilns were of different geometrical dimensions, gas temperature profiles, and operating schemes. Evaluation of the POHC DRE's for each of these facilities provided an opportunity for direct comparison of their thermal destruction processes.

Major conclusions with regard to waste destruction were that low kiln process temperatures at site I may have resulted in low DRE of major volatile POHC's. DRE's less than 99.99 percent at this site were associated with kiln temperatures on the order of 590 to 650°C (1,100 to 1,200°F). Whereas, for site II, POHC DRE's generally greater than 99.99 percent were associated with kiln process temperatures in the range of 1,120 to 1,180°C (2,050 to 2,150°F). Gas residence time in both kilns was equivalent at about 2.5 sec. Lowest DRE's were recorded for the volatile compounds benzene and chlorobenzene which failed to meet 99.99 percent destruction levels at both sites. In addition, toluene for site I and carbon tetrachloride for site II also failed to meet this destruction level. A trend of lower DRE with lower POHC concentration in the waste fuels was identified. This trend was apparent for both site I and site II results. This trend may indicate the significance of PIC formation and contribution to emissions of low waste concentration POHC's. DRE of Freon 113 artificially added to the waste as a tracer compound was significantly higher than other volatile POHC's in the wastes. This result was attributed to two reasons. First, Freon 113 is generally less thermally stable than other compounds and second, its concentration in the fuel was significantly higher than that of other POHC's in these wastes.

Total volatile PIC emissions ranged on the average between 25 to 80 percent of the total POHC breakthrough levels. For site I, where low POHC DRE's were recorded, the highest PIC emissions were by carbon tetrachloride (60 percent of total PIC's). For site II, where high POHC DRE's were recorded, the highest PIC emissions were by chloromethane (95 percent of total PIC's).

Among the trace metal priority pollutant species lead, copper, and zinc were present in the waste fuel at site I at the highest concentration ranging from about 400 to 700 ppm. Emission rates of these metals accounted for only 0.01 to 0.11 percent of the input rate. Collection by the filter baghouse and adsorption in the clay product were the two primary reasons attributed for the retention of these metals in the system. Lead, zinc, chromium, and copper were the primary metals with concentrations in the range of 90 to 975 ppm in the waste fuel burned at site II aggregate kiln. Stack emissions of these metals accounted for 1.4 to 9.9 percent of the total input rate to the kiln. The contribution of these metals by the pulverized coal during cofiring was negligible. Therefore, trace metal emission results obtained during this program indicate that the aggregate kiln at site II although more efficient in thermal destruction of organics had a higher percentage of trace metals emissions. This result is attributed to the higher process temperatures in the site II kiln which may prevent metal adsorption in the product or the flue gas entrained particulate matter, and lower particulate removal efficiency of the wet scrubber compared with the baghouse.

APPENDIX A

SAMPLING PROTOCOL

A.1 CONTINUOUS MONITORING SYSTEM

Rack-mounted electronic monitors and recorders located in a mobile emissions laboratory were used for the continuous measurement of SO_2, O_2, CO_2, CO, NO_x, and total unburned hydrocarbons (TUHC) at the stack. Figure A-1 illustrates the continuous flue gas extractive sampling system and monitor arrangement. Flue gas is drawn through an in-stack filter and a stainless-steel probe to a gas conditioning and refrigeration system designed to remove water. An unheated line is then used to bring the conditioned gas to the monitors. Calibration gases were used to monitor and correct instrument drift. Both internal and external calibrations were performed daily. For external calibrations, the gases followed the same path as the flue gas being monitored, whereas for internal calibrations, the gases just went through the monitors. Table A-1 lists the instrumentation used in the continuous monitoring van during the test program. Emission levels were recorded at 5-min intervals on an Autodata 9 data logger and on data sheets.

A.2 HCl EMISSIONS

A modified EPA method 6 sampling system was us ed to measure HCl emissions (Figure A-2). Diluted NaOH in 100-ml quantities was used in each of the first two impingers. The third impinger was empty and the fourth contained a known weight of silica gel to remove moisture from the flue gas. Two 40-min samples were taken each day at a rate of ~0.5 ft^3/min. Each of the samples were taken concurrently with a VOST sample.

A.3 VOLATILE ORGANIC EMISSIONS

A volatile organic sampling train (VOST) was used to measure the low molecular weight volatile organic compounds (boiling points $\leq$110°C) in the

1. _In situ_ filter 1.0μ, 99.999 percent efficient
2. Duct
3. 316 stainless steel probe
4. Four pass conditioner-dryer, 316 stainless steel internals
5. 3/8-inch unheated Teflon
6. Teflon-lined sample pump
7. 3/8-inch unheated Teflon
8. Rotameter
9. 1/4-inch Teflon tubing
10. Calibration gas manifold
11. Calibration gas selector valve
12. Calibration gas cylinders
13. Backpressure regulator
14. Auxillary analysis port

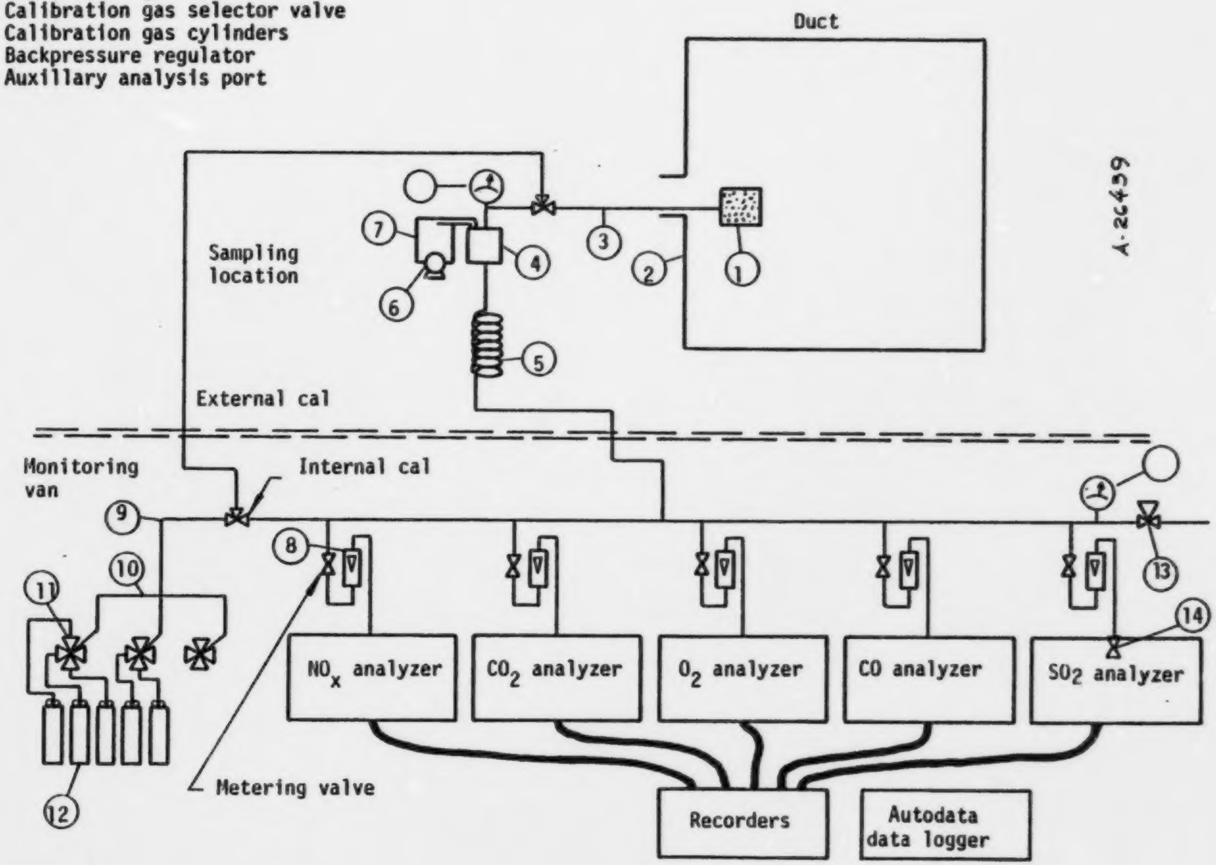

Duct
A-26439
Sampling location
External cal
Monitoring van
Internal cal
Metering valve
1
2
3
4
5
6
7
8
9
10
11
12
13
14
NO$_x$ analyzer
CO$_2$ analyzer
O$_2$ analyzer
CO analyzer
SO$_2$ analyzer
Recorders
Autodata data logger

Figure A-1. Schematic for continuous, extractive sampling system.

TABLE A-1. CONTINUOUS MONITORING EQUIPMENT IN THE ACRUEX MOBILE LABORATORY

Instrument	Principle of operation	Manufacturer	Instrument model	Range
NO NO_x	Chemiluminescence	Thermo Electron	10 AR	0 to 2.5 ppm 0 to 10 ppm 0 to 25 ppm 0 to 100 ppm 0 to 250 ppm 0 to 1,000 ppm 0 to 2,500 ppm 0 to 10,000 ppm
CO (1)	Nondispersive infrared (NDIR)	ANARAD	500R	0 to 1,000 ppm
CO (2)	Nondispersive infrared (NDIR)	ANARAD	500R	0 to 1.0 percent (10,000 ppm)
CO_2	Nondispersive infrared (NDIR)	ANARAD	AR500	0 to 20 percent
SO_2	Photometric	Du Pont	400	0 to 300 ppm 0 to 3,000 ppm
O_2	Fuel cell	Teledyne		0 to 5 percent 0 to 10 percent 0 to 25 percent
Sample gas conditioner	Refrigerant dryer-condenser	Hankinson	E-4G-SS	10 scfm
Strip chart recorder	Dual pen analog	Linear	400	0 to 10 mV 0 to 100 mV 0 to 1V 0 to 10V

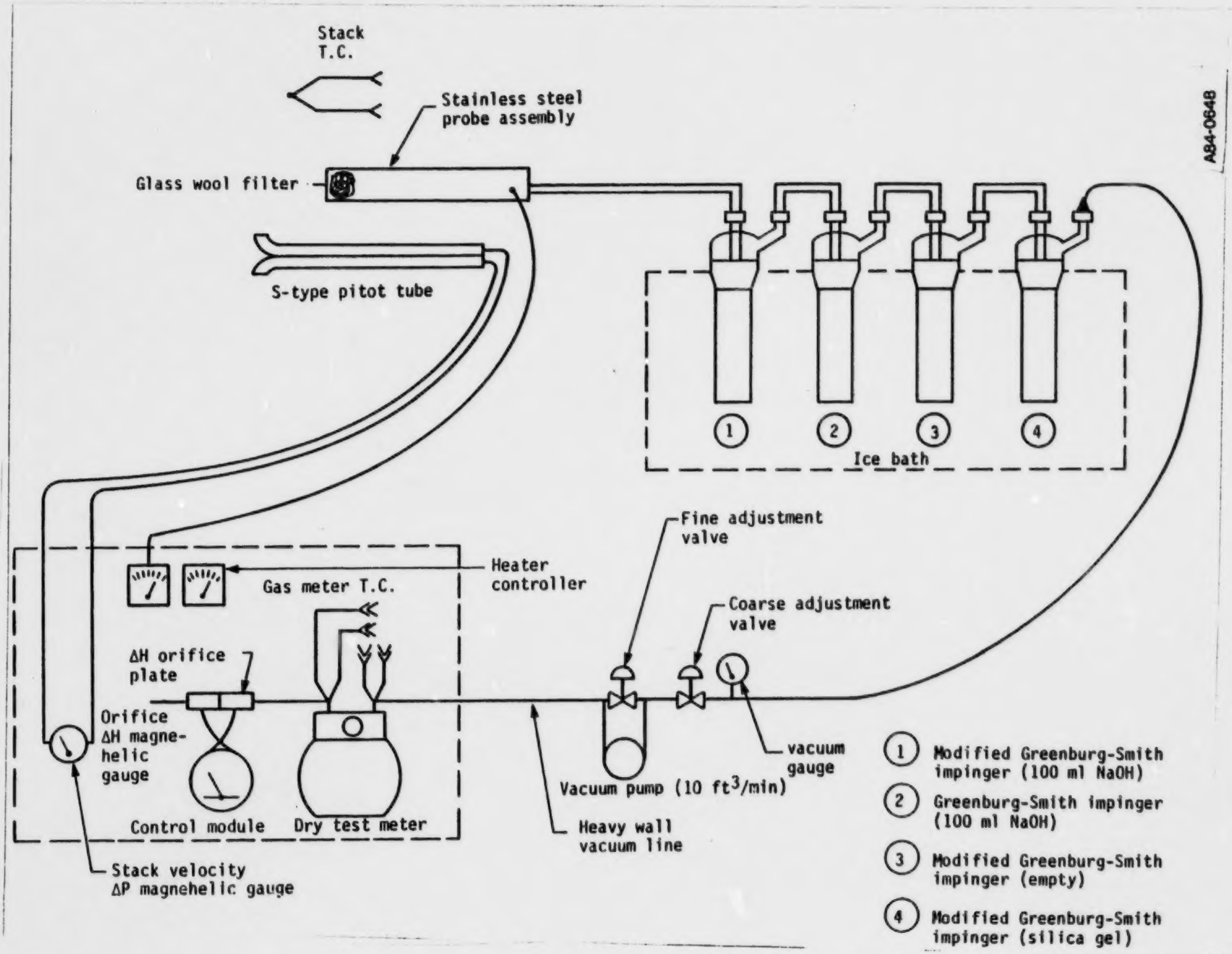

Stack
T.C.
Stainless steel
probe assembly
A84-0648
Glass wool filter
S-type pitot tube
1
2
3
4
Ice bath
Fine adjustment
valve
Heater
controller
Gas meter T.C.
Coarse adjustment
valve
ΔH orifice
plate
Orifice
ΔH magne-
helic
gauge
vacuum
gauge
Vacuum pump (10 ft³/min)
Control module
Dry test meter
Heavy wall
vacuum line
Stack velocity
ΔP magnehelic gauge
① Modified Greenburg-Smith impinger (100 ml NaOH)
② Greenburg-Smith impinger (100 ml NaOH)
③ Modified Greenburg-Smith impinger (empty)
④ Modified Greenburg-Smith impinger (silica gel)

Figure A-2. Schematic of HCl sampling train.

flue gas (Figure A-3). The train consists of two organic sorbent traps connected in series. The first trap contained ~1.6g of the porous polymer Tenax-GC, 35/60 mesh. The second trap consisted of ~1.0g each of Texax-GC and petroleum-based charcoal. Prior to their use in the field, each trap was conditioned to remove organic compounds. Conditioning consisted of baking each trap at 190°C with a N_2 purge for an 8-hr period. The traps were then desorbed at 190°C directly into a GC/FID. If a trap showed no contaminant peaks greater than 20 ng for benzene or toluene, it was considered ready for sampling. The trap was then sealed at each end with 1/4-in. compression fittings, placed in a clean, muffled culture tube and sealed in a metal can in preparation for shipping.

The remaining components of the VOST were washed with Alconox and distilled water in an ultrasonic cleaner. They were then rinsed with DI water, methanol, and HPLC water and muffled overnight.

Before each field test, the entire system was leak checked at approximately 15 to 20 in. of vacuum. A leakage rate of 0.05 l/min was considered acceptable. Ambient air was drawn through a charcoal filled tube to prevent organic contamination while bringing the system back to ambient pressure.

Three sets of samples and a field blank were obtained daily. A total sample volume of 20 liters per set of traps was taken over a 40-min period (0.5 l/min). At the beginning and end of each run, time, temperatures, pressures, and meter volume were recorded by the operator upon completion of a run, the sampled traps were removed from the train, sealed, returned to their original culture tubes, and stored in a metal can on ice. Two clean

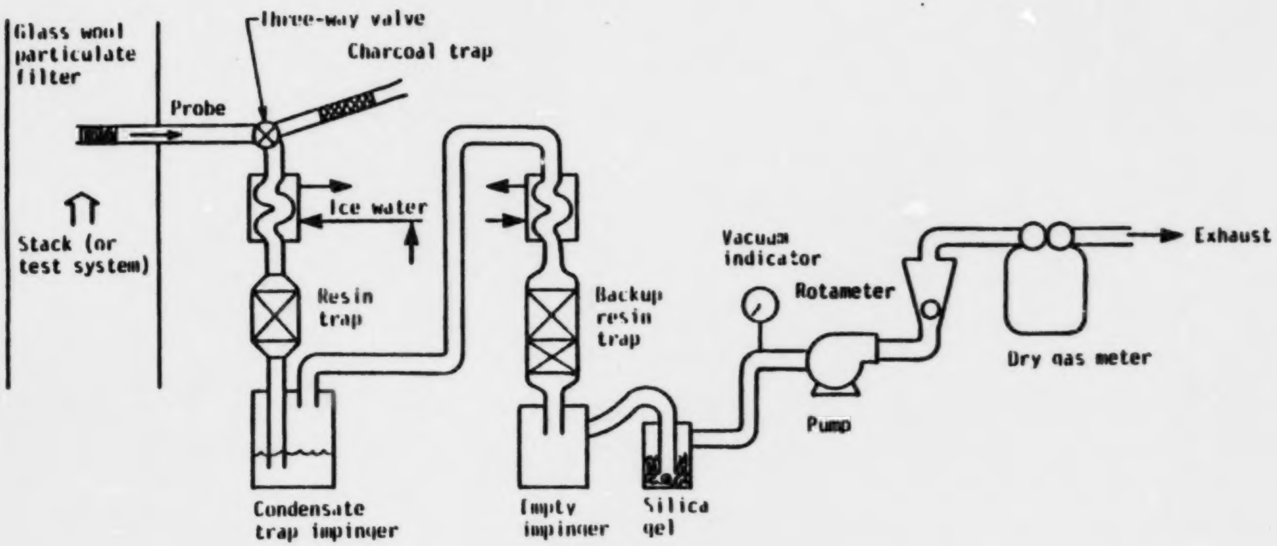

Glass wool particulate filter
Three-way valve
Charcoal trap
Probe
Stack (or test system)
Ice water
Resin trap
Condensate trap impinger
Backup resin trap
Empty impinger
Silica gel
Vacuum indicator
Rotameter
Pump
Dry gas meter
Exhaust

Figure A-3. Schematic of volatile organic sampling train.

traps were placed in the system and leak checked in preparation for a new run. After a series of three sets of traps were run, the components were rinsed with HPLC water into a VOA vial. All of the VOST samples were removed from the site and stored on ice. The components of the train were cleaned as before and dried in an oven at 200°C overnight.

At the conclusion of the test program, a pair of unused traps was designated as the trip blank. This pair of traps was brought to the test site but never removed from their culture tubes. Their analysis allows for correction of the samples for contamination due to the effects of transportation and time.

A.4 SEMIVOLATILE AND NONVOLATILE ORGANIC EMISSIONS

At site I, higher molecular weight organics (>C_7 with approximate boiling range >100°C), primarily semivolatile and nonvolatile, were collected using a modified EPA Method 5 sampling system modeled after the system developed by Battelle-Columbus Laboratories. Figure A-4 illustrates this sampling system. The XAD-2 organic sorbent in amounts of about 65g was prepacked in the laboratory in a glass module. Prior to field testing, the sampling system was rigorously cleaned in the laboratory using a nitric acid bath solution followed by several rinses using methanol, methylene chloride, and distilled water. The purpose of this cleaning was to minimize contamination of the gas sample and provide inert surfaces. Specific sampling system parts subjected to this cleaning were: the glass-lined probe, stainless-steel nozzles, Teflon-lined filter holder, condenser, sorbent module, four impingers, and associated tubing.

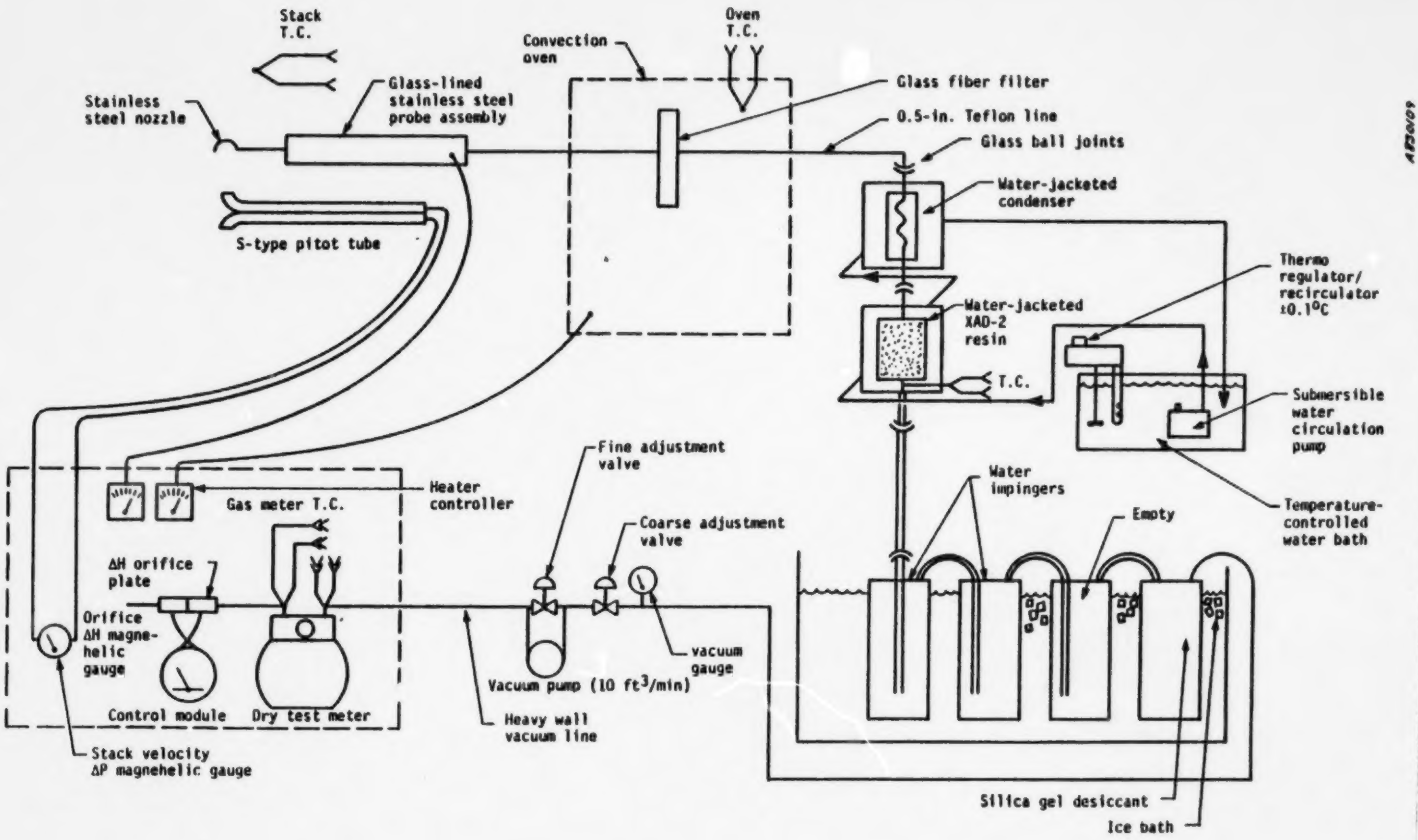

Stack T.C.
Stainless steel nozzle
Glass-lined stainless steel probe assembly
Convection oven
Oven T.C.
Glass fiber filter
0.5-in. Teflon line
Glass ball joints
Water-jacketed condenser
Water-jacketed XAD-2 resin
T.C.
Thermo regulator/ recirculator ±0.1°C
Submersible water circulation pump
Temperature-controlled water bath
S-type pitot tube
Heater controller
Gas meter T.C.
ΔH orifice plate
Orifice ΔH magne-helic gauge
Control module
Dry test meter
Stack velocity ΔP magnehelic gauge
Fine adjustment valve
Coarse adjustment valve
vacuum gauge
Vacuum pump (10 ft3/min)
Heavy wall vacuum line
Water impingers
Empty
Silica gel desiccant
Ice bath
A830109

Figure A-4. Modified EPA method 5 train.

During field testing both the condenser and the XAD-2 sorbent module were water jacketed to maintain the flue gas temperature entering the XAD-2 sorbent at approximately 20°C (68°F). The first modified impinger was used to trap organic module condensate. The remaining distilled H_2O and silica gel impingers were used to trap remaining moisture in the flue gas. The convection-heated oven contained a 142-mm-diameter glass-fiber filter. A cyclone and filter combination was unnecessary because of anticipated low particulate emissions.

Gas sampling was done isokinetically across the stack per EPA Methods 1 through 4. A typical sampling rate of about 280 ml/s (0.6 dscfm) was adjusted to maintain isokinetic conditions as dictated by stack gas velocity. Total sample volumes were set at approximately 7 dscm (250 dscf) to give organic component detection limits in the range of about 0.1 to 0.6 µg/dscm. Only one modified method 5 test was run daily for a 6-hour period at the site I location.

At site II, three standard EPA Method 5 tests were conducted daily. The flue gas sample was pulled from the heated filter directly into the impinger train. Three 1-hour isokinetic tests were performed daily. It was deemed more important to obtain several particulate emissions data values rather than to measure the semi-volatile and nonvolatile emissions from the stack.

A.5 FUEL SAMPLING

Samples of the fuel burned during the collection of flue gas samples were taken throughout the test program. These samples were then analyzed for the RCRA Appendix VIII compounds and other major constituents so that the input quantity of these compounds could be determined. The blended waste fuel for site I (waste oil/waste solvent mixture) was sampled at the strainer station near the vertical and horizontal storage tanks. The blended fuel was not heated at this location; however, downstream of this location, the fuel was passed through electrical preheaters, strainers and a flow meter. Flow was monitored at this location. Waste fuel samples were collected throughout the daily test period. Four samples were taken at times corresponding to the VOST test period. Since the fuel collected at the strainer location required approximately one-half hour to reach the burner front, fuel samples were taken prior to the start of a VOST run when possible.

Site II burned waste solvent both with and without coal. Two coal samples were collected from the feed bin supplying coal to the ball mill. A grab sample was collected from this bin once during each of the two days when emission testing was performed and the kiln was fired both with coal and waste solvent. These two samples were subjected to ultimate, proximate, and trace metals analyses. Waste solvent samples were collected at the burner front. The timing of sample collection was coordinated with the performance of VOST runs. Four grab fuel samples were collected each test day.

A.6 AIR POLLUTION CONTROL DEVICE COLLECTED PARTICULATE MATTER

Dry particulate samples were collected from the air pollution control devices at both sites I and II. At Site I, dust collected by the baghouse was sampled from the rotary air-lock valve located on the pneumatic discharge line from the baghouse hopper screw conveyer. Two or three grab samples were collected throughout each day and composited into one sample.

The site II kiln was equipped with a mechanical collector ahead of a spray scrubber. The dust collected by the mechanical collector was sampled three times periodically throughout each test day and composited into one sample for that day.

A.7 LIQUID SCRUBBER INFLUENT AND EFFLUENT

The site II number 5 rotary kiln was equipped with a wet scrubber unit using "once-through" scrubbing water. Both the influent and effluent streams to this scrubber were sampled. Throughout each test day, four grab samples were collected. Samples for volatile organics were collected in 40-ml glass vials with Teflon-lined caps and sealed so that no entrapped air was present. Samples collected for subsequent chloride analysis were composited from the four daily grab samples, stored in glass containers, and preserved with nitric acid to a pH level of less than 2. All liquid samples were stored on ice or under refrigeration until analysis.

APPENDIX B

ANALYTICAL PROTOCOL

B.1 HCl STACK GAS EMISSIONS

The HCl emissions were determined by the argentometric titration of the modified EPA Method 6 impinger solutions. Titrations were performed using a standard silver nitrate solution and potassium dichromate indicator. Blanks of the sodium hydroxide solutions used during the test program were also analyzed in order to account for contamination in the samples. The analyses were performed according to procedures set forth in Standard Methods for the Analysis of Wastes and Wastewater, 13th ed., Method 112A.

B.2 FLUE GAS VOLATILE ORGANIC COMPOUNDS

The VOST samples were analyzed by GC/MS according to the EPA VOST Protocol (1). Each pair of traps used in a test run was thermally desorbed and analyzed for EPA method 624 priority pollutants in addition to several other major constituents. At site I, the traps were also analyzed for acetone, ethanol, 2-butanone (MEK), Freon 113, isopropanol, propanol, and xylenes. Methanol was not analyzed for because it is the solvent used for the standards and also because its mass is below the scanning range. At site II, the traps were analyzed for priority pollutants in addition to styrene, xylenes, C_3-alkyl benzenes, Freon 113, 2-butanone (MEK), 4-methyl-2-pentanone, and di-isopropyl ether.

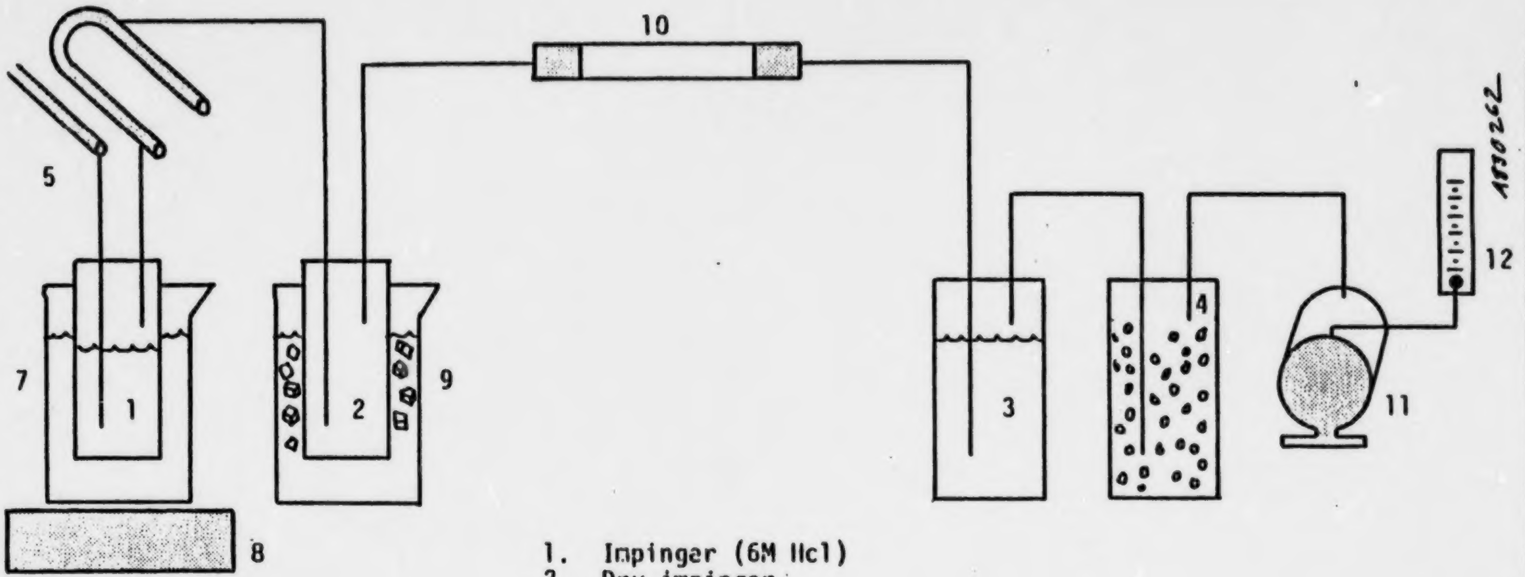
Laboratory, trip, and field blank traps were analyzed in the same manner as the samples. Method blanks were also run to account for contamination in the GC/MS system. All samples and blanks were spiked with d_8-toluene for determination of percent recoveries. The following subsections detail the analytical procedure of VOST samples.

B.2.1 Conditioning

The first analytical activity related to volatile organic sampling was the conditioning of the Tenax-GC sorbent in each trap. This conditioning was done to ensure cleanliness of the sorbent for use in sampling. Each trip was conditioned by temperature programming to 250°C for a minimum of 4 hours (typically 8 hours) with a 30 ml/min purge flow of nitrogen (99.95 percent) through the trap followed by cooling for at least one-half hour. This cycle was repeated at least four times per trap. The traps were then tested for cleanliness by thermal desorption of 200°C and GC/FID analysis. Conditioning was repeated until the FID analysis did not show any compounds above 20 ng.

B.2.2 Spiking

Prior to thermal desorption and GC/MS analysis, all sample Tenax traps were spiked with 100 ng each of toluene-d_8, using the flash vaporization technique in which the spiking solution is vaporized and carried onto the trap with the carrier gas. For the recovery study, the compounds were spiked directly onto the trap or spiked using the sample spike generation system illustrated in Figure B-1. The intake air was filtered through charcoal to remove vapors present in the ambient laboratory air. The intake air was then saturated with water vapor and fortified with hydrogen chloride by bubbling the air through impinger no. 1, which contained hydrochloric acid and was heated by a boiling waterbath. The compounds of interest were injected in methanol solutions into a "U" tube which was heated to a temperature of 100°C by a heating tape. The airstream was passed through a dry impinger cooled in an ice bath. This impinger simulated the knockout impinger used in field sampling to remove excess water vapor from the flue gas. The sample was



1. Impinger (6M HCl)
2. Dry impinger
3. Impinger (1M NaOH)
4. Impinger (silica gel)
5. Charcoal tube inlet filter
6. Heated "U" tube with crimp top end seals
7. Water bath
8. Hot plate
9. Ice bath
10. Tenax trap
11. Pump
12. Rotameter

Figure B-1. Apparatus for laboratory-scale generation of spiked tenax trap.

trapped on a 3/8-in. OD (5 mm ID) x 12 in. glass trap packed with 35/60 mesh Tenax GC. (The traps employed for these experiments were from the same lot as those used for field sampling.) The pump was protected from water and hydrogen chloride vapors by means of impingers no. 3 and 4 containing sodium hydroxide and silica gel. The gas flowrate was controlled at ~200 ml/min by means of a rotameter connected to the exit of the pump. This flowrate was the same as that employed for field operations.

Prior to spiking any of the traps, the entire system was leak checked by capping off the connection to the inlet filter and operating the pump at maximum flow. Leaks were assumed to be absent when no bubbles were observed in impinger no. 3. Tenax and Tenax/charcoal traps were spiked with 100 ng of d_8-toluene. Percent recoveries of these compounds ranged from 70 to 110 percent for both types of traps.

B.2.3 Thermal Desorption and GC/MS Analysis

The Tenax traps were desorbed at 200°C with a helium flow of about 40 ml/min for 10 min onto a 6-ft, 1 percent SP-10000 on Carbopack B (60/80 mesh) gas chromatographic column held at 260°C and held for 10 min. All traps were desorbed and analyzed satisfactorily. GC/MS operating conditions are summarized in Table B-1. Table B-2 summarizes the volatile organics sought in the analysis of Tenax and Tenax/charcoal traps.

B.3 SEMIVOLATILE ORGANIC ANALYSIS OF STACK EMISSIONS

Particulate emissions and semivolatile organic pollutants were measured in the flue gas samples collected at site I by the modified EPA Method 5 sampling train. Figure B-2 illustrates the general sample preparation and analysis protocol for semivolatile and nonvolatile organic pollutants.

TABLE B-1. GC/MS OPERATING CONDITIONS FOR VOST SAMPLE ANALYSIS

Instrument	Finnigan 1020 GC/MS system interfaced with an Incos 2300 data system
Carrier gas	Helium at 40 ml/min
Temperature program	45°C (3 min) to 250°C (12 min) at 8°C/min
Injector temperature	200°C (for spiking internal standards)
Scan range	40 to 250 amu
Ionizing energy	70 eV
Scan rate	3.0 sec/scan
Acquisition time	1,000 scans
Separator oven temperature	250°C
Manifold temperature	100°C
Injection port temperature	220°C (on gas chromatograph)
Column	1 percent SP-100 on Carbopack B 60/80 mesh

TABLE B-2. VOLATILE ORGANICS SOUGHT IN GC/MS ANALYSIS

Chlorinated Aliphatics

Chloromethane
Dichloromethane
Chloroform
Tetrachloromethane
Chloroethane
1,1-dichloroethane
1,2-dichloroethane
1,1,1-trichloroethane
1,1,2-trichloroethane
1,1,2,2-tetrachloroethane
1,2-dichloropropane
Hexachlorocyclohexane
Vinyl chloride
1,1-dichloroethylene
1,2-dichloroethylene
Trichloroethylene
Tetrachloroethylene
Alkyl chloride
1,3-dichloropropene
Chloroprene

Ethers

Ethylene oxide
Propylene oxide

Chlorinated Ethers

Epichlorohydrin
2-chloroethyl vinyl ether

Aldehydes

Acetaldehyde
Acrolein

Amines and Nitriles

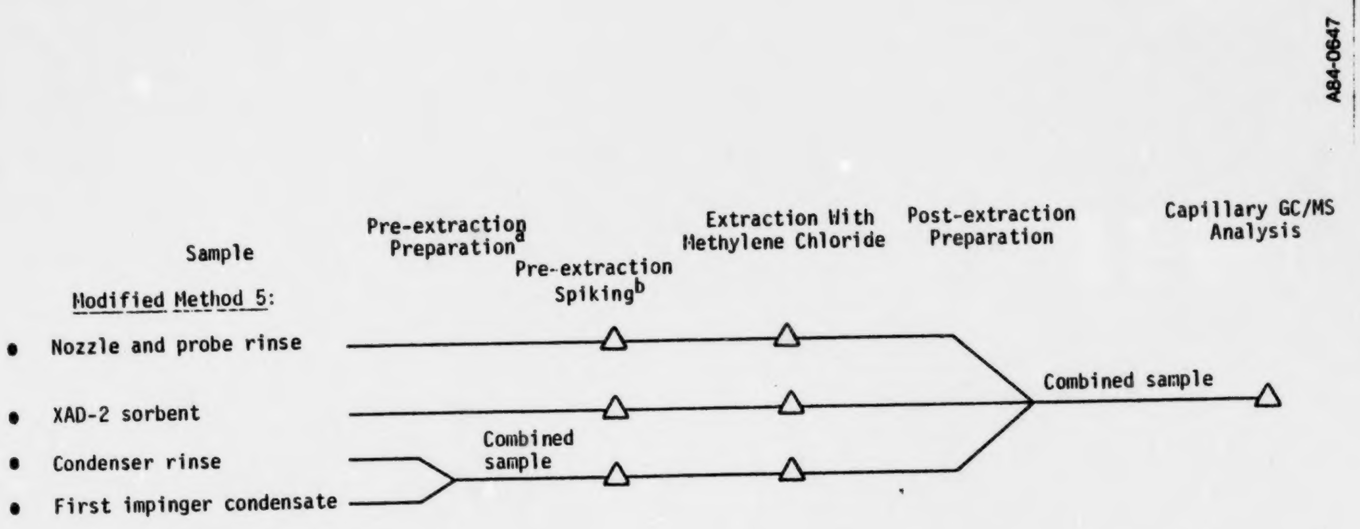
Acrylonitrile

Aromatic Hydrocarbons

Benzene
Toluene
Ethyl benzene
o-xylene
m-xylene
p-xylene

Chlorinated Aromatics

Chlorobenzene


A84-0647
Sample
Pre-extraction Preparation[a]
Pre-extraction Spiking[b]
Extraction With Methylene Chloride
Post-extraction Preparation
Capillary GC/MS Analysis
Modified Method 5:
Nozzle and probe rinse
XAD-2 sorbent
Condenser rinse
First impinger condensate
Combined sample
Combined sample

[a] Includes gravimetric quantification of combined nozzle and probe rinses and filter catch and volumetric quantification of impinger condensates and rinses

[b] Includes pre-extraction spiking of samples with surrogate compounds

Figure B-2. Semivolatile organic analysis procedure.

Prior to organic analysis of the modified Method 5 samples, the nozzle and probe rinses were evaporated, and the weights were combined with the appropriate filter weights to calculate total particulate emissions. For the determination of the semivolatile organic emissions, the volume of the individual probe/nozzle rinse and impinger, rinses were measured and then combined prior to being extracted. The combined sample was then Soxhlet extracted for 8 hours using methylene chloride. Organics trapped in the XAD-2 sorbent were extracted in a similar manner. The condenser rinse and the condensate of the first impinger were combined and extracted at pH >12 and three times at pH <2 using methylene chloride. All modified Method 5 sample extracts from a test were then combined to form one sample and then dried over sodium sulfate and concentrated to 1 ml.

Particulate filters from the modified Method 5 trains were not extracted and included in the semivolatile compound analysis because they were used in their entirety for the trace metals analysis. The minimal weight gain of the filters necessitated their use solely for the metals analysis so that sufficient materials was present for detection.

The modified Method 5 extracts were analyzed by GC/MS for semivolatile organics according to EPA Method 625. Principal semivolatile and nonvolatile organics sought in the analysis are the priority pollutants listed in Table B-3. Also, concentrations of nonpriority pollutants were estimated using response factors for similar components. The GC/MS operating conditions used for the analyses appear in Table B-4.

TABLE B-3. COMPOUNDS SOUGHT IN THE EPA METHOD 625 GC/MS ANALYSIS AND THEIR DETECTION LIMITS[a]

Acid Compounds

2,4,6-trichlorophenol	5	2-nitrophenol	5
p-chloro-m-cresol	5	4-nitrophenol	20
2-chlorophenol	5	2,4-dinitrophenol	20
2,4-dichlorophenol	5	4,6-dinitro-o-cresol	20
2,4-dimethylphenol	5	Pentachlorophenol	5
		Phenol	1

Base Neutral Compounds

1,2,4-trichlorobenzene	1	Benzo(c)phenanthrene	40
1,2-dichlorobenzene	1	Bis(2-chloroethoxy)methane	1
1,2-diphenylhydrazine (as azobenzene)	1	Bis(2-chloroethyl)ether	1
		Bis(2-chloroisopropyl)ether	1
1,3-dichlorobenzene	1	Bis(2-ethylhexyl)phthalate	1
1,4-dichlorobenzene	1	Butyl benzyl phthalate	1
2,4-dinitrotoluene	1	Chrysene	1
2,6-dinitrotoluene	1	Di-n-butyl phthalate	1
2-chloronaphthalene	1	Di-n-octyl phthalate	1
3,3'-dichlorobenzidine	5	Dibenzo(a,h)anthracene	5
3-methyl cholanthrene	40	Dibenzo(c,g)carbazole	40
4-bromophenyl phenyl ether	1	Diethyl phthalate	1
4-chlorophenyl phenyl ether	1	Dimethyl phthalate	1
7,12-dimethyl benz(a)anthracene	40	Fluoranthene	1
N-nitrosodi-n-propylamine	5	Fluorene	1
N-nitrosodimethylamine	NA	Hexachlorobenzene	1
N-nitrosodiphenylamine	1	Hexachlorobutadiene	1
Acenaphthene	1	Hexachlorocyclopentadiene	1
Acenaphthylene	1	Hexachloroethane	1
Anthracene	1	Indeno(1,2,3-cd)pyrene	5
Benzo(ghi)perylene	5	Isophorone	1
Benzidine	20	Naphthalene	1
Benzo(b)fluoranthene	1	Nitrobenzene	1
Benzo(k)fluoranthene	1	Perylene	40
Benzo(a)anthracene	1	Phenanthrene	1
Benzo(a)pyrene	1	Pyrene	1

[a] In nanograms per microliter injected

TABLE B-4. GC/MS OPERATING CONDITIONS FOR MODIFIED METHOD 5 TRAIN

Column	SE54-30N
Injector temperature (°C)	260°C
Detector temperature (°C)	280°C
Transfer line temperature (°C)	255°C
Split flow (ml/min)	37
Sweep flow (ml/min)	7
Temperature program	20°C, 2 min → 270°C @ 10°C/min, 30 min hold at 270°C
Multiplier voltage	-2100V
Filament current	0.51A
Mass range	35 to 450 amu
Scan rate	1 sec/scan
Total scans acquired	2,550

B.3.1 XAD-2 Blank

An XAD-2 blank exposed to field contaminants in the sample recovery laboratory was analyzed by GC/MS to estimate the background contamination. The results of sample blank analysis were used in determining the actual concentration of compounds in the samples. All emission results reported were corrected for this background concentration.

B.3.2 Surrogate Samples

The XAD-2 resins from each test and the blank XAD-2 resin were spiked with surrogates before extraction. The XAD resin was applied with the surrogate compounds and then Soxhlet extracted with methylene chloride. The probe and nozzle washes were Soxhlet extracted with methylene chloride. The back-half impinger condensates and rinses were applied with the surrogate compounds and extracted according to EPA Method 625. Generally, recoveries of these compounds ranged from about 33 to 78 percent in the base neutral fraction. As with spiked sample blanks, the percent recovery of surrogates was not used to correct the analytical results of field samples. Percent recoveries represent estimates of the degree of uncertainty in the emissions.

B.4 FUELS ANALYSES

Samples of the fuel obtained from site I were analyzed by GC/MS for Priority Pollutant Volatile and Semivolatile Organics according to EPA Methods 624 and 625. Four grab samples of the blended fuel were obtained throughout each test day. Five ml from each set of four grab samples were composited in a 40-ml VOA vial.

The three resulting composite samples were then analyzed for volatile organics first by being diluted. This was accomplished by placing 1.0 ml of composited sample into a 5-ml volumetric flask and adding hexadecane. 1.00 ml of this solution was transferred to a 25-ml flask and diluted to the mark with tetraglyme. These diluted samples were analyzed for priority pollutant volatile organics and any other detectable purgeable organics. Every peak present in the reconstructed ion chromatogram (RIC) was subjected to NBS library search and identified.

Semivolatile organics in the three daily composite fuel samples were also measured. Each composite sample was thoroughly mixed and diluted 100 times with methylene chloride. Each diluted composite sample was then analyzed by GC/MS for semivolatile organic compounds according to EPA Method 625.

The site II fuel samples (waste solvent mixture) were composited to form samples by withdrawing 5.0 ml from each grab sample while the bulk sample was continuously stirred with a teflon-coated magnetic stirring bar, and combining this aliquot with the other subsamples in a 40-ml VOA vial. The composite samples were than diluted 100 times in methanol, 100 µl of this solution was then added to 5.0 ml of HPLC water and analyzed for volatile organics by the purge and trap technique according to EPA Method 624.

The site II fuel samples (i.e., waste solvent mixture) was analyzed for semivolatile organic compounds in the same manner previously described for the site I samples.

In addition to the volatile and semivolatile organic compound analyses, the fuel samples were subjected to proximate, ultimate, trace metals, chlorides, and specific gravity determinations. The test methods used are listed in table B-5.

TABLE B-5. ANALYSIS METHODS FOR FUEL SAMPLES

	Waste solvent	Waste oil/ solvent blend	Coal
Specific gravity	ASTM D1298	ASTM D287	NA
Total chlorides	ASTM D808 (modified)	ASTM D808 (modified)	NA
Proximate analysis			
Ash	ASTM D482	ASTM D482	ASTM D3174
Moisture	ASTM D1744	ASTM D95	ASTM D3173
Volatile matter	ASTM D189[a]	ASTM D189[a]	ASTM D3175
Fixed carbon	ASTM D189[a]	ASTM D189[a]	ASTM D3175
Higher heating value	ASTM D240	ASTM D240	ASTM D2015
Ultimate analysis			
Carbon	Perkin Elmer 240B	Perkin Elmer 240B	Perkin Elmer 240B
Hydrogen	Perkin Elmer 240B	Perkin Elmer 240B	Perkin Elmer 240B
Oxygen	By difference	By difference	By difference
Sulfur	ASTM D129	ASTM D129	ASTM D2492
Nitrogen	Perkin Elmer 240B	Perkin Elmer 240B	Perkin Elmer 240B
Trace metals	Flame and flameless Atomic absorption	Flame and flameless Atomic absorption	Flame and flameless Atomic absorption

[a] Fixed carbon based on Conradson carbon residue less ash content. Volatile matter determined by difference (includes moisture).

NA — Not applicable or not analyzed.

REFERENCE FOR APPENDIX B

1. "Protocol for the Collection and Analysis of Volatile POHC's Using VOST," Environdyne Engineers, Inc., prepared for Technical Support Office, Industrial Environmental Research Laboratory, U.S. EPA, Research Triangle Park, North Carolina, August 1983.

APPENDIX C

KILN OPERATIONS AND SAMPLING SCHEDULES

TABLE C-1. FLOWRATE AND SAMPLING DATA -- SITE I

Description	Test 1	Test 2	Test 3
Flue gas flowrate:			
m^3/s	10.4	9.9	10.5
10^3 dscfm	22.1	20.9	22.3
Flue gas sampled:			
• Modified Method 5			
m^3	3.63	9.81	9.93
dscf	128.2	346.3	350.8
• VOST[a]			
Liters	23.028 20.832 20.042	20.018 20.510 20.002	21.328 20.120 20.061
dscf	0.813 0.736 0.708	0.707 0.724 0.706	0.753 0.711 0.708
• HCl[b]			
m^3	0.61 0.71	0.67 0.66	0.72 0.61
dscf	21.6 25.1	23.5 23.2	25.6 21.6
Percent moisture in flue gas[c]	28.6	28.2	24.7
Percent O_2 (dry) in flue gas	15.8	16.1	16.0

[a] Three VOST samples, each consisting of a Tenax and a Tenax/charcoal trap, were taken daily.
[b] Two HCl samples were taken each day.
[c] Moisture calculated from modified Method 5 data.

TABLE C-2. FLOWRATE AND SAMPLING DATA -- SITE II

Description	Test 1	Test 2	Test 3	Test 4
Flue gas flowrate:[a]				
m^3/s	5.0 4.2 4.0	3.0 3.1 3.1	3.1 3.1 3.0	3.1 3.1 3.2
10^3 dscfm	10.6 8.8 8.4	6.3 6.6 6.6	6.6 6.5 6.4	6.6 6.5 6.8
Flue gas sampled:				
• Method 5				
m^3	1.83 0.86 1.48	1.05 1.09 1.08	1.11 1.09 1.08	1.10 1.05 1.12
dscf	64.7 30.4 52.2	36.9 38.4 38.3	39.1 38.6 38.2	38.7 37.0 39.4
• VOST[b]				
Liters	19.892 19.470 20.018	20.002 21.125 20.105	20.008 20.003 20.080	20.064 20.006 20.065
dscf	0.703 0.687 0.707	0.706 0.746 0.710	0.707 0.706 0.709	0.709 0.707 0.709
• HCl[c]				
m^3	0.78 0.77	0.77 0.76	0.76 0.77	0.77 0.76
dscf	27.5 27.3	27.1 27.0	26.9 27.3	27.2 26.8
Percent moisture in flue gas[d]	13.1 11.9 12.3	9.0 9.9 9.8	9.5 10.0 9.4	9.4 9.8 9.1
Average percent moisture	12.4	9.6	9.6	9.4
Average percent O_2 (dry) in stack gas	9.8	8.0	7.7	7.5

---

[a] Three EPA Method 5 tests were run daily.

[b] Three VOST samples, each consisting of a Tenax and a Tenax/charcoal trap, were taken daily.

[c] Two HCl samples were taken each day.

[d] Moisture calculated from Method 5 data.

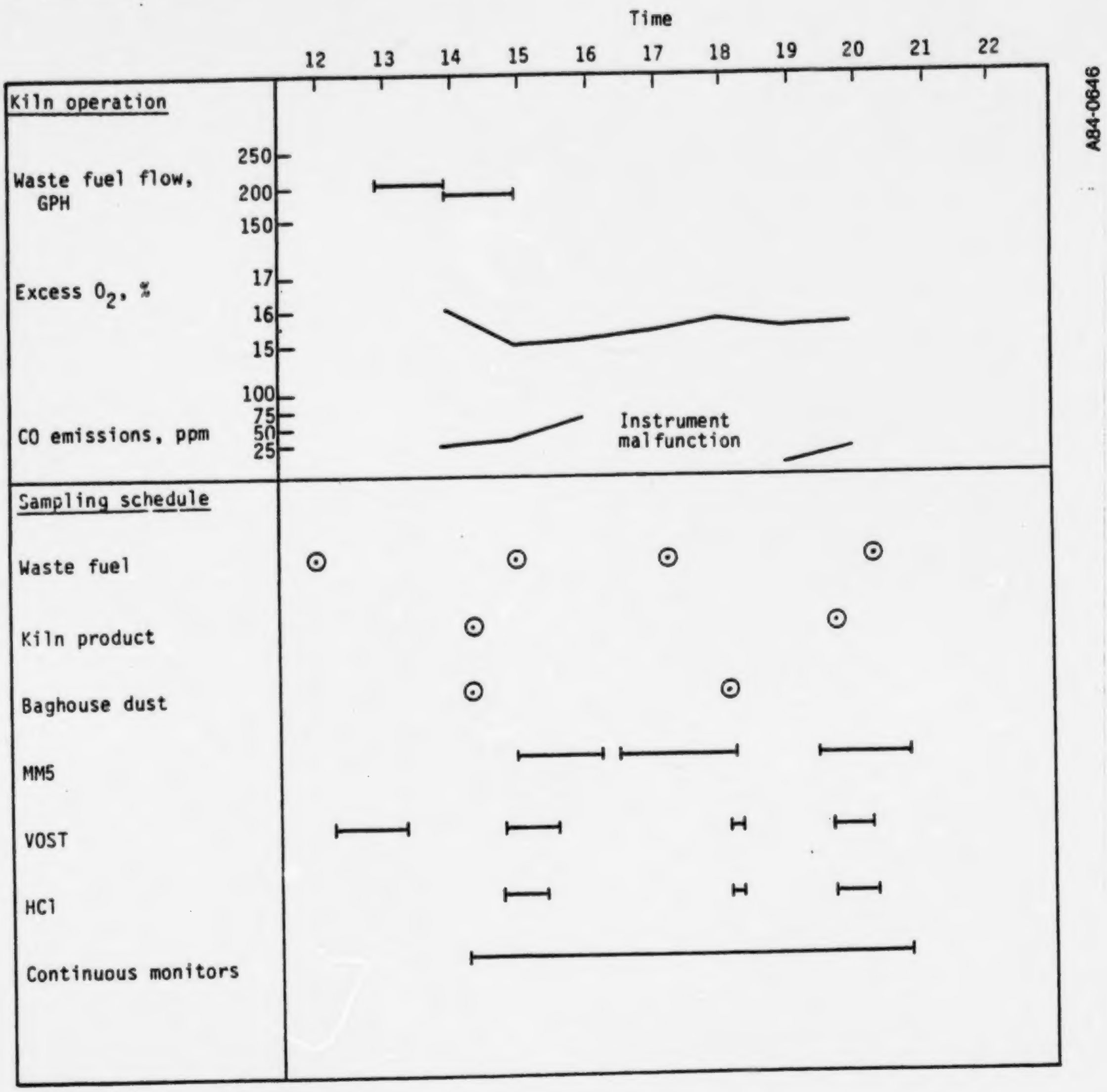


Figure C-1. Testing schedule -- site I (test 1, 2/14/84).

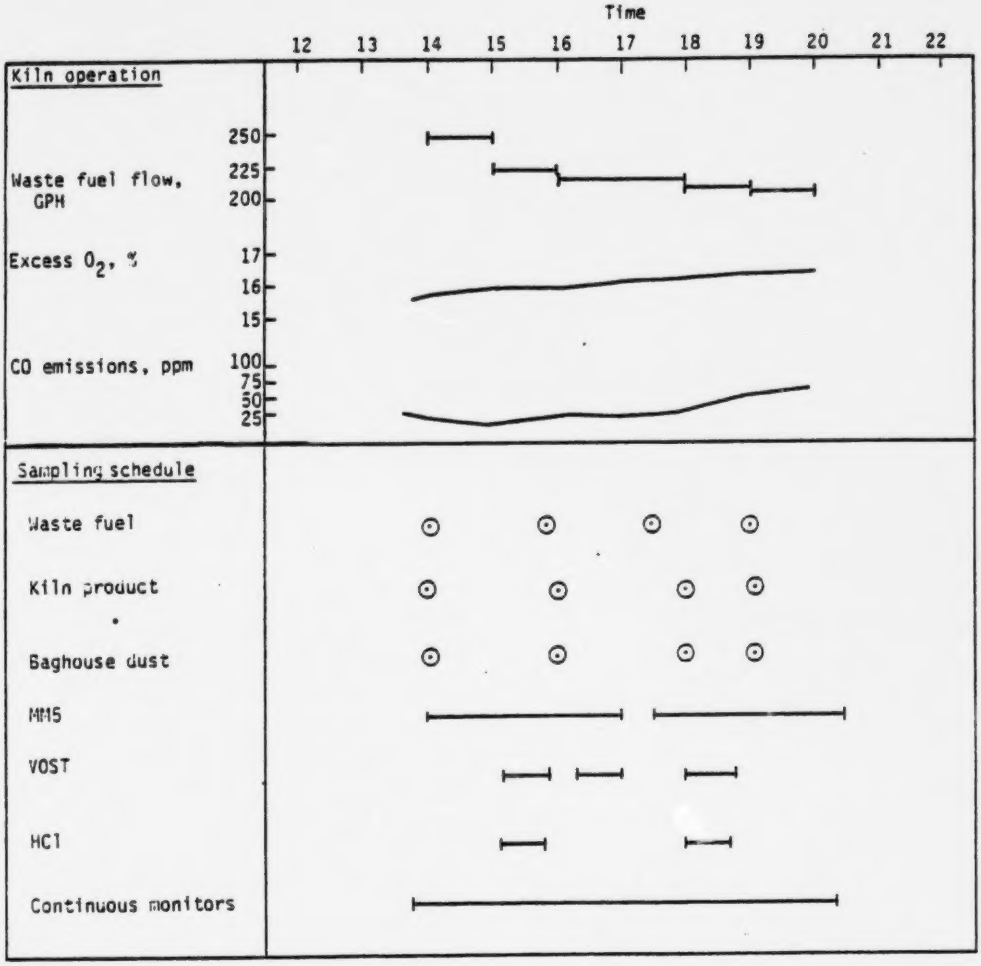


Figure C-2. Testing schedule — site I (test 2, 2/15/84).

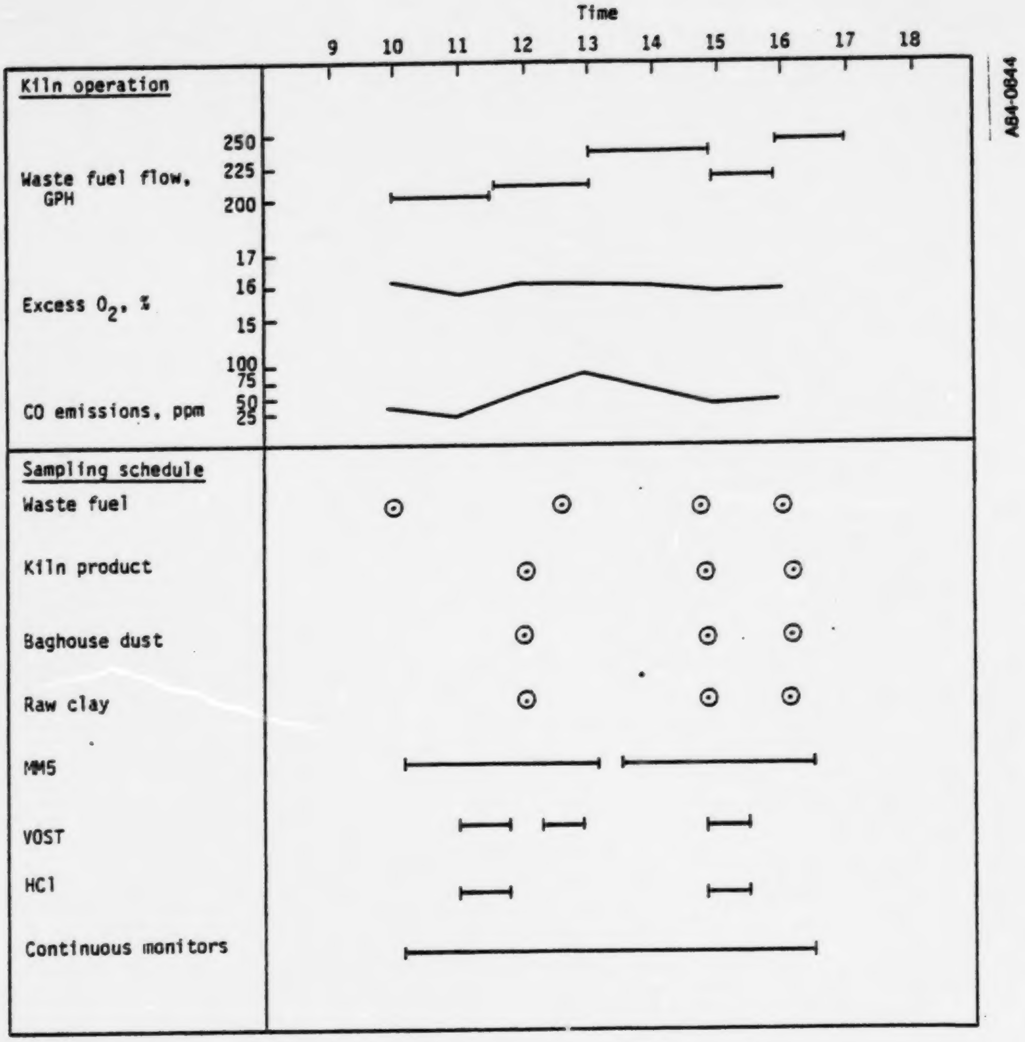


Figure C-3. Testing schedule -- site I (test 3, 2/16/84).

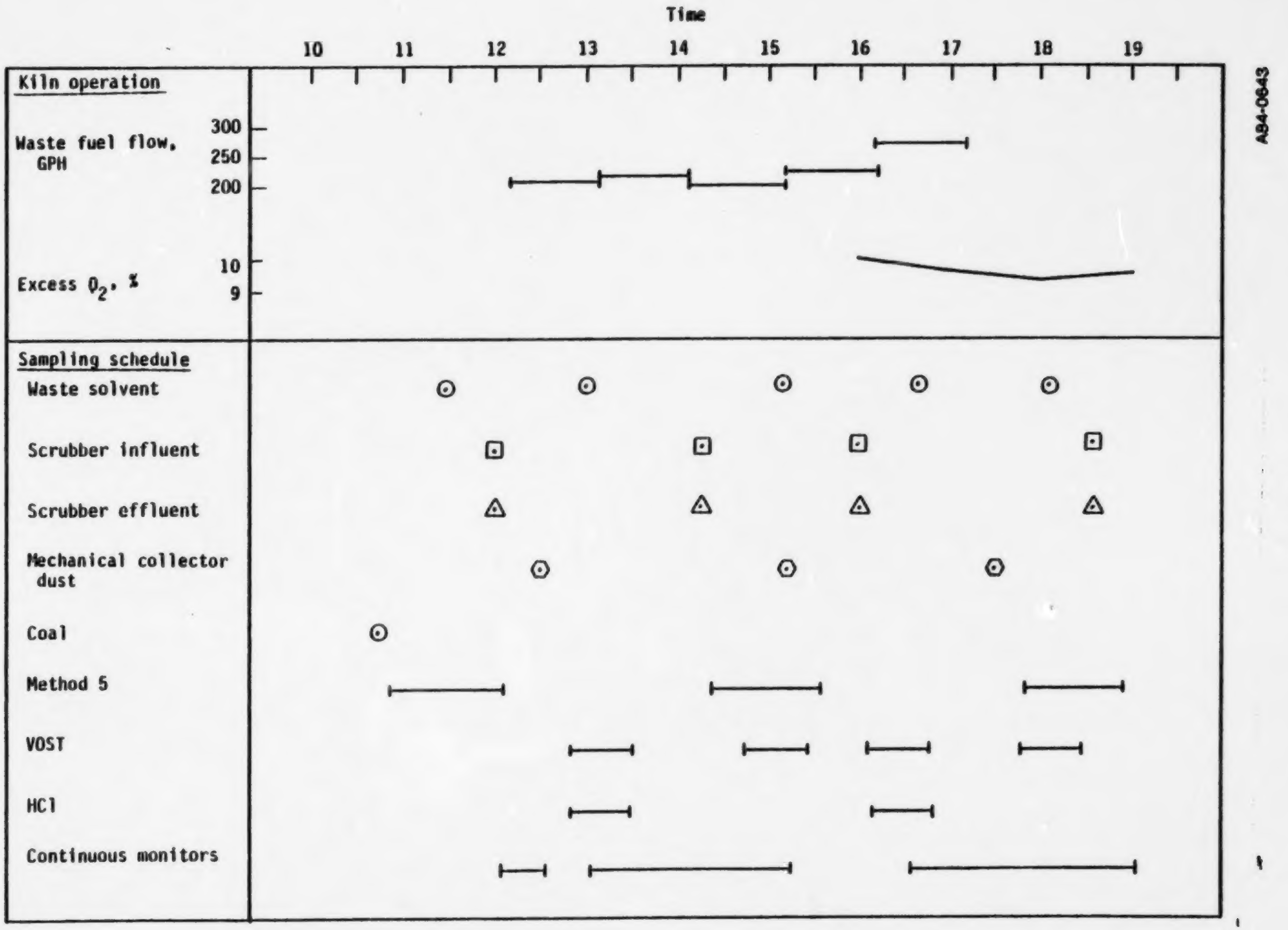


Figure C-4. Testing schedule -- site II (test 1, 3/6/84).

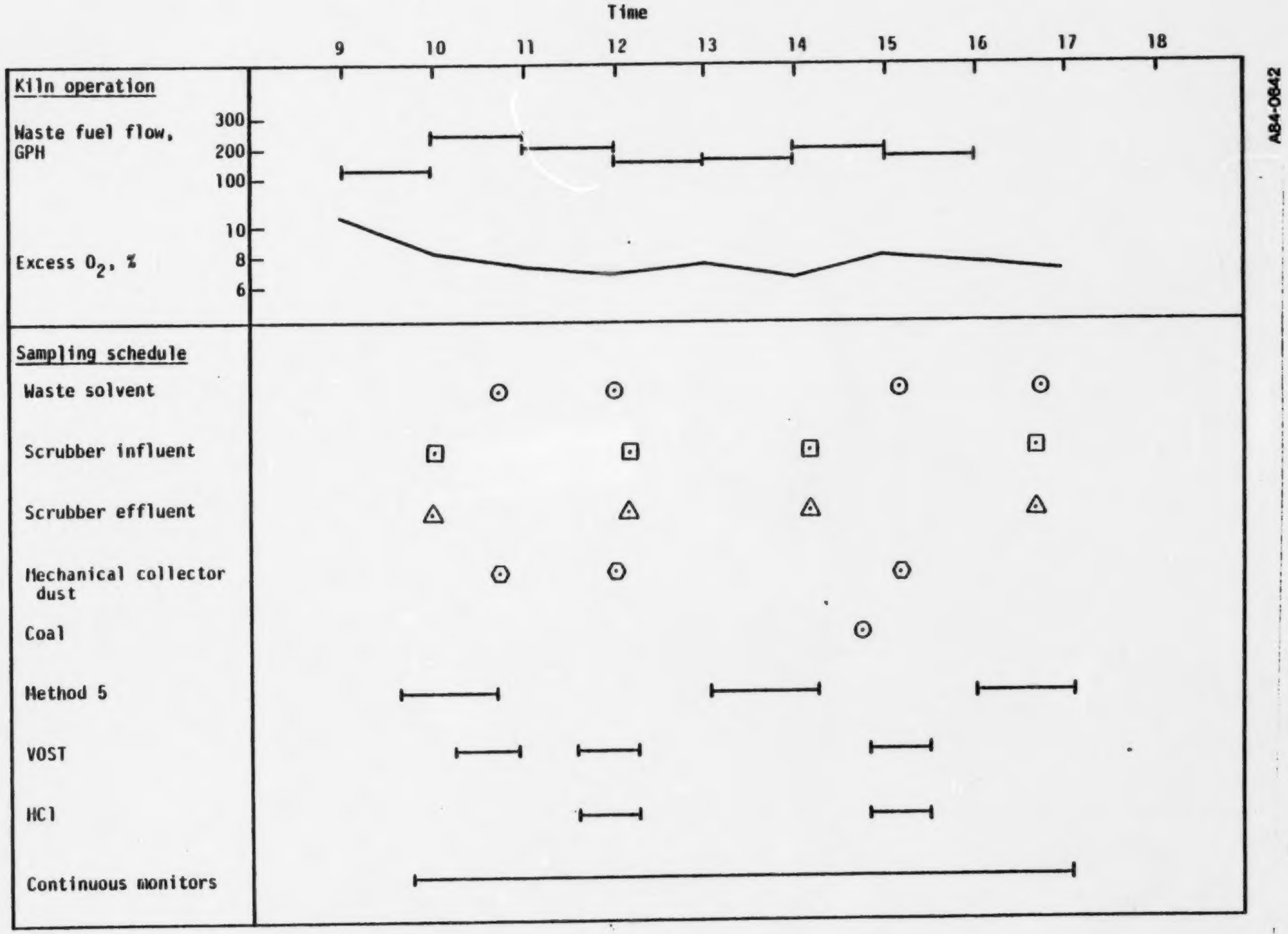


Figure C-5. Testing schedule -- site II (test 2, 3/7/84).

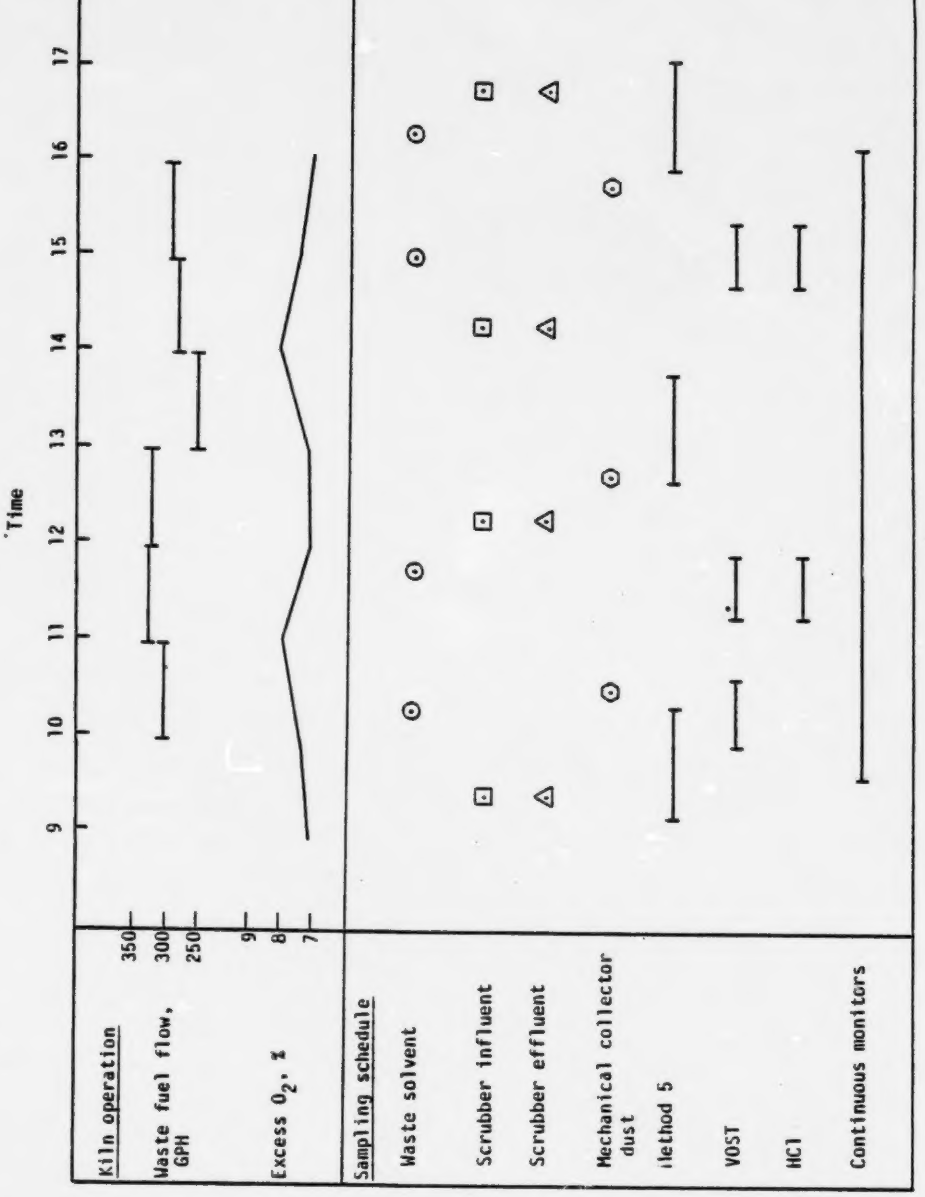


Figure C-6. Testing schedule -- site II (test 3, 3/8/84).

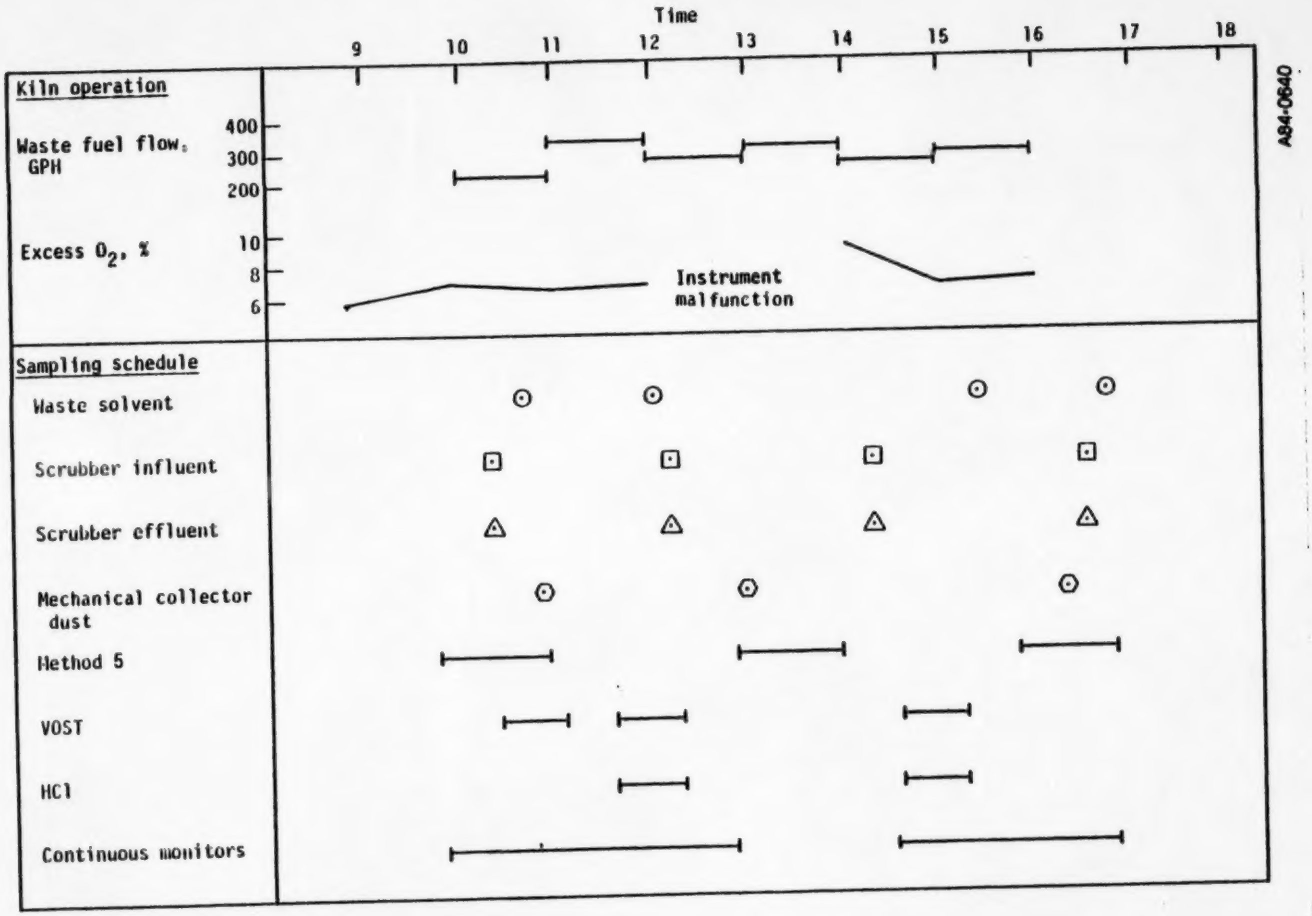


Figure C-7. Testing schedule -- site II (test 4, 3/9/84).

TABLE C-3. KILN OPERATING CONDITIONS -- SITE I

Date	Time	Blended fuel temperature (°F)	Fuel pressure (psig)	Instantaneous fuel flow rate (gph)	Average fuel flow rate (gph)
2/14	1315	157	35	238	205
2/14	1440	125	32	250	195
2/14	1945	119	32	225	
2/15	1345	170	30	245	250
2/15	1450	158	30	231	225
2/15	1605	156	35	250	222
2/15	1745	153	31	218	218
2/15	1840	152	31	216	215
2/15	2015	150	31	209	
2/16	935	158	31	224	209
2/16	1130	170	30	231	213
2/16	1300	168	31	226	240
2/16	1455	170	32	224	216
2/16	1545	170	32	222	248
2/16	1700	165	31	233	

APPENDIX D

ANALYTICAL RESULTS

TABLE D-1. SAMPLE IDENTIFICATION NUMBERS — SITE I

Sample description Date	Test 1 2-14-84	Test 2 2-15-84	Test 3 2-16-84	Blank
Blended waste fuel grab samples				
1 of 4	902782	902812	902835	
2 of 4	902783	902813	902842	
3 of 4	902794	902825	902843	
4 of 4	902795	902834	902845	
Modified method 5:				
Probe and nozzle rinse	902802	902827	902858	902779
Filter	902803	902828	902859	902778
XAD-2 cartridge	902804	902829	902860	902777
Impingers	902805/806	902830/833	902861/864	902780
VOST traps:				
Run 1 (Tenax/Tenax charcoal)	902784/785	902814/815	902846/847	902790/791[a]
Run 2 (Tenax/Tenax charcoal)	902788/789	902818/819	902848/849	902854/855[a]
Run 3 (Tenax/Tenax charcoal)	902797/798	902820/821	902852/853	
Field blank (Tenax/Tenax charcoal)	902786/787	902816/817	902850/851	
HCl impingers:				
Run A	902792/793	902811	902840	902781
Run B	902796	902826	902844	902841

[a] Trip blanks.

ACUREX
Corporation

Energy & Environmental Division

Acurex/ES

Attention: Walt Wyss/2-2260

March 8, 1984
Acurex ID#: 8402-021
Client PO#: 307953.20
Page 1 of 4

Subject: Analysis of Four Pairs of Tenax Traps, Received 2/14/84, According to EPA VOST Protocol for Volatile Organics

The above referenced samples were analyzed by GC/MS on February 14, 1984, in strict accordance with the EPA VOST Protocol. Each pair of traps--Tenax and Tenax/Charcoal--were thermally desorbed and analyzed for EPA Method 624 Priority Pollutants as well as acetone, ethanol, 2-butanone (MEK), 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), isopropanol, propanol and xylenes. Methanol could not be analyzed for as its mass is below the scanning range and, also, as it is the solvent used for the standards. Additionally, there was a problem in analyzing for isopropanol as it co-eluted with diethyl ether (a contaminant in the solvent methanol), which contributed to the quantitation mass.

Results of sample analyses are given in Table 1. Results of method blank analyses are given in Table 2 and recovery data from a spiked trap is given in Table 3.

If you have any questions, please call.

Prepared by: William G. Hellier
William G. Hellier
Staff Chemist

Approved by: Viorica Lopez-Avila
Viorica Lopez-Avila, Ph.D.
Technical Director

WGH/VLA/ats

555 Clyde Avenue, P.O. Box 7555, Mountain View, CA 94039 (415) 964-3200 Telex: 34-6391 TWX: 910-7796593

Table 1. Results of Volatile Organic Analysis

Sample ID	Concentration (ng/Trap)			
	Test 1A[a] 53 & 40A	Test 1B[a] 54 & 18 A Field Blank	Test 1C[b] 3 & 12A	Trip Blank[b] 50 & 6A
Priority Pollutants				
Chloromethane	239	453	483	212
Bromomethane	29	ND	ND	ND
Vinyl chloride	206	ND	52	ND
Dichloromethane	217	79	339	65
1,1-Dichloroethane	72	ND	200	ND
Chloroform	18	ND	7	ND
1,1,1-Trichloroethane	94	6	195	1
Carbon Tetrachloride	335	51	1870	ND
Trichloroethylene	50	ND	46	ND
Benzene	8500	10	322	7
Tetrachloroethylene	177	ND	84	ND
Toluene	2780	12	577	10
Chlorobenzene	57	ND	31	ND
Ethylbenzene	389	2	56	ND
Nonpriority Pollutants				
Acetone	29	3	58	4
Ethanol	ND	ND	ND	ND
Isopropanol	146	276	ND	326
2-Butanone	4	ND	10	ND
Styrene	272	1	137	1
Xylenes	1260	5	222	3
1,1,2-Trichloro-2,2,1-Trifluoroethane	578	10	255	2
Cyclohexane	ND	ND	ND	ND
Detection Limit	1	1	1	1
Percent Surrogate Recovery				
Toluene-d_8	89	89	89	89

ND - Not detected
a - Transport tubes for traps #40A & 54 were received at lab broken
b - Tenax traps #3 & 50 were received at lab broken - transferred prior to analysis

Table 2. Results of Method Blanks

Sample ID	Concentration (ng/Trap)			
	Purge A Blank	Purge B Blank	Purge Blank	Trap C Blank
Priority Pollutants				
Chloromethane	ND	ND	4	119
Dichloromethane	47	43	64	40
1,1,1-Trichloroethane	2	3	3	ND
1,2-Dichloropropane	ND	1	ND	ND
Trichloroethylene	ND	2	ND	ND
1,1,2-Trichloroethane	ND	2	ND	ND
Benzene	2	3	2	7
Bromoform	ND	ND	10	ND
1,1,2,2-Tetrachloroethane	3	14	19	ND
Toluene	26	8	3	5
2-Chloroethylvinylether	ND	5	ND	ND
Ethylbenzene	2	4	2	1
Nonpriority Pollutants				
Acetone	4	13	3	2
Ethanol	ND	ND	ND	ND
Isopropanol*	324	266	280	270
2-Butanone	8	ND	ND	ND
Styrene	2	6	3	1
Xylenes	3	5	4	3
1,1,2-Trichloro-2,2,1-	1	5	ND	ND
Trifluoroethane	1	5	ND	ND
Cyclohexane	1	5	1	ND
Detection Limit	1	1	1	1
Percent Surrogate Recovery				
Toluene-d_8	96	98	99	97

* Interference from diethyl ether in MeOH

ND - Not detected

Table 3. Percent Recovery from a Spiked Trap

Priority Pollutants	
Chloromethane	700
Bromomethane	144
Vinyl Chloride	130
Chloroethane	126
Dichloromethane	121
1,1-Dichloroethylene	134
1,1-Dichloroethane	131
Trans-1,2-Dichloroethylene	130
Chloroform	130
1,2-Dichloroethane	93
1,1,1-Trichloroethane	128
Carbon Tetrachloride	128
Dichlorobromomethane	114
1,2-Dichloropropane	96
Trichloroethylene	107
Chlorodibromomethane	66
1,1,2-Trichloroethane	62
Benzene	108
Bromoform	44
Tetrachloroethylene	100
1,1,2,2-Tetrachloroethane	42
Toluene	104
Chlorobenzene	94
Ethylbenzene	98
Nonpriority Pollutants	
Acetone	38
Ethanol	41
Isopropanol	43
2-Butanone	42
Styrene	85
Xylenes	96
1,1,2-Trichloro-2,2,1-trifluoroethane	151
Cyclohexane	124
Percent Surrogate Recovery	
Toluene-d_8	95

ACUREX
Corporation

Energy & Environmental Division

Acurex Corporation
Environmental Sciences
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

April 5, 1984
Acurex ID#: 8402-025
Client PC#: 307953.20
Page 1 of 4

Attention: Walt Wyss

Subject: Analysis of 11 Pairs of Tenax Traps by GC/MS,
Received 2/18/84

The subject samples were analyzed by GC/MS according to the EPA VOST protocol. Sample results are listed in Table 1. Purge and trap blank results are listed in Table 2. Recovery from spiked traps is listed in Table 3.

If you have any questions, please call.

Prepared by: William G. Hellier
Staff Chemist

Approved by: Viorica Lopez-Avila, Ph.D.
Technical Director

WGH/VLA/wp

Table 1. VOST Results (ng/pair traps)

ID Number	902797, 902798	902814 902815	902816, 902817	902818, 902819	902820, 902821	902846, 902847	902848, 902849	902850, 902851	902852, 902853	902854, 902855	Lab Blank
Trap Number	2,21A	1, 36A	7, 23A	56, 9A	5, 20A	17, 25A	42, 45	58, 34A	52, 5A	11, 30A	55, 7A
Test	1D	2A	2B (FB)	2C	2D[1]	3A	3B	3C (FB)	3D	3E (TB)	
	ng/pair	ng/pair	ng/pair	ng/pair	ng/pair	ng/pair	ng/pair	ng/pair	ng/pair	ng/pair	ng/pair
Priority Pollutants:											
Chloromethane	179	284	65	388	199	292	131	127	128	95	83
Bromomethane	20	17	ND	16	34	16	15	ND	ND	ND	ND
Vinyl Chloride	26	26	ND	33	68	25	43	ND	39	ND	ND
Chloroethane	ND	ND	ND	ND	25	ND	ND	ND	ND	ND	ND
Dichloromethane	112	178	62	53	63	77	84	91	38	73	48
1,1-Dichloroethylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	61	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	3	16	ND	3	3	3	2	22	2	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	116	98	1	140	56	27	35	58	113	10	20
Carbon Tetrachloride	884	35	ND	82	7	9	7	ND	ND	ND	ND
Dichlorobromoethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	6	11	ND	ND	ND	ND	ND	ND
Trichloroethylene	19	13	ND	3	ND	ND	1	ND	1	ND	9
Chlorodibromoethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethylene	19	ND	ND	2	ND	ND	ND	ND	ND	ND	3
Benzene	345	450	ND	233	501	221	267	5	242	6	10
Bromoform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethylene	19	27	ND	17	9	6	5	ND	6	ND	6
1,1,2,2-Tetrachloroethane	ND	ND	ND	16	ND	ND	ND	ND	ND	ND	ND
Toluene	416	511	3	351	444	404	414	3	351	5	9
Chlorobenzene	21	38	ND	26	43	28	40	ND	34	ND	ND
1,3-Dichloropropene(cis)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-Dichloropropene(trans)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloroethylvinylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	55	121	ND	54	89	67	60	1	71	ND	4
Non-Priority Pollutants:											
Acetone	420	619	ND	255	255	235	229	130	409	ND	108
Ethanol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Isopropanol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone	345	158	ND	21	41	37	24	ND	21	ND	ND
Styrene	130	49,400	ND	1,990	893	139,700	9,200	1	21,200	ND	4
Xylenes	216	362	ND	274	375	428	202	2	458	ND	4
1,1,2-Trichloro-2,2,1-trifluoroethane	103	40	ND	81	39	38	74	15	27	ND	ND
Cyclohexane	ND	ND	ND	ND	ND	ND	ND	7	ND	ND	45
C(3)-Alkylbenzenes	134	777	ND	363	197	1,710	2,810	ND	873	ND	ND
Percent Surrogate Recovery:											
d8-Toluene	94	91	90	91	95	93	84	86	82	90	93
Detection Limit	1	1	1	1	1	1	1	1	1	1	1

[1] Trap no. 5 broken badly at stem

Table 2. Purge and Tenax Trap Blank

	Purge Blank 2-27-84 ng	Trap Blank 2-27-84 ng	Purge Blank 2-28-84 ng	Trap Blank 2-28-84 ng	Purge Blank 3-6-84 ng	Trap Blank 3-6-84 ng
Priority Pollutants:						
Chloromethane	ND	ND	ND	84	ND	205
Bromomethane	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND
Dichloromethane	36	45	41	63	48	63
1,1-Dichloroethylene	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethylene	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	3	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND
Dichlorobromoethane	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND
Trichloroethylene	ND	ND	ND	ND	ND	
Chlorodibromoethane	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethylene	ND	ND	ND	4	ND	ND
Benzene	ND	ND	2	10	2	4
Bromoform	ND	ND	ND	ND	ND	ND
Tetrachloroethylene	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	18	ND	ND
Toluene	ND	2	3	4	5	4
Chlorobenzene	ND	ND	ND	ND	ND	ND
1,3-Dichloropropene(cis)	ND	ND	ND	ND	ND	ND
1,3-Dichloropropene(trans)	ND	ND	ND	ND	ND	ND
2-Chloroethylvinylether	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	3	ND	3	1	2
Non-Priority Pollutants:						
Acetone	ND	ND	ND	ND	51	34
Ethanol	ND	ND	ND	ND	ND	120
Isopropanol	ND	ND	ND	ND	ND	ND
2-Butanone	ND	ND	ND	ND	ND	30
Styrene	ND	3	2	4	ND	ND
Xylenes	ND	ND	2	5	3	4
1,1,2-Trichloro-2,2,1-trifluoroethane	ND	ND	ND	ND	ND	ND
Cyclohexane	ND	ND	ND	ND	ND	ND
C(3)-Alkylbenzenes	ND	ND	ND	ND	ND	ND
Percent Surrogate Recovery:						
d8-Toluene	96	91	100	92	101	83
Detection Limit	1	1	1	1	1	1

Table 3. Spiked Trap Recovery

Date	Trap std 200 ng 2-28-84 % Recovery	Trap std 200 ng 3-6-84 % Recovery
Priority Pollutants:		
Chloromethane	143	394
Bromomethane	91	109
Vinyl Chloride	91	123
Chloroethane	90	132
Dichloromethane	90	112
1,1-Dichloroethylene	90	148
1,1-Dichloroethane	97	130
Trans-1,2-Dichloroethylene	96	130
Chloroform	98	126
1,2-Dichloroethane	98	89
1,1,1-Trichloroethane	98	141
Carbon Tetrachloride	105	158
Dichlorobromoethane	93	99
1,2-Dichloropropane	80	68
Trichloroethylene	91	74
Chlorodibromoethane	82	63
1,1,2-Trichloroethylene	67	88
Benzene	90	63
Bromoform	68	58
Tetrachloroethylene	84	100
1,1,2,2-Tetrachloroethane	60	69
Toluene	84	86
Chlorobenzene	80	94
Ethylbenzene	79	86
Non-Priority Pollutants:		
Acetone	*	*
Ethanol	*	*
Isopropanol	*	*
Styrene	146	65
Xylenes	152	75
1,1,2-Trichloro-2,2,1-trifluoroethane	*	131
Cyclohexane	*	*
Percent Surrogate Recovery:		
d8-Toluene	91	82

*Compounds not spiked

ACUREX
Corporation

Energy & Environmental Division

April 5, 1984
Acurex ID#: 8402-026A
Client PC#: 307953.20
Page 1 of 2

Acurex Corporation
Environmental Sciences
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

Attention: Walt Wyss

Subject: Analysis of Three Composite Fuel Samples for Volatile Organics by GC/MS, Received 2/22/84

The subject samples were first composited as follows: 5.00 ml from each set of four grab samples was removed while the grab samples were stirred with a Teflon stirring bar, and composited in a 40 ml VOA vial.

The three resulting composite samples were then diluted by placing 1.0 ml into a 5 ml volumetric flask and adding hexadecane. Next, 1.00 ml of the sample/hexadecane solution was placed into a 25 ml volumetric flask and diluted with tetraglyme.

These diluted samples were analyzed for Priority Pollutant Volatile Organics and any other detectable purgeable organics by purging 200 ml of diluted sample with 5 ml HPLC water in accordance with EPA Method 624. Every peak present in the Reconstructed Ion Chromatogram (RIC) was subjected to NBS library search and identified. Analysis results are listed in Table 1. In addition to the compounds listed in Table 1, a large number of hydrocarbons (primarily branched alkanes) were also identified.

If you have any questions, please call.

Prepared by: ______________________
William G. Hellier
Staff Chemist

Approved by: Viorica Lopez Avila
Viorica Lopez-Avila, Ph.D.
Technical Director

WGH/VLA/wp

Table 1. Concentration (mg/L)

Sample ID (Customer)	902812 902813 902825 902834	902782 902783 902794 902795	902835 902842 902843 902845
Parameter	mg/L	mg/L	mg/L
Priority Pollutants:			
Chloromethane	ND	ND	ND
Bromomethane	ND	ND	ND
Vinyl Chloride	ND	ND	ND
Chloroethane	ND	ND	ND
Dichloromethane	ND	ND	ND
1,1-Dichloroethylene	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND
Trans-1,2-Dichloroethylene	ND	ND	ND
Chloroform	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND
1,1,1-Trichloroethane	346	364	355
Carbon Tetrachloride	ND	ND	ND
Dichlorobromoethane	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND
Trichloroethylene	36	38	32
Chlorodibromoethane	ND	ND	ND
1,1,2-Trichloroethylene	ND	ND	ND
Benzene	57	37	46
Bromoform	ND	ND	ND
Tetrachloroethylene	149	147	121
1,1,2,2-Tetrachloroethane	ND	ND	ND
Toluene	912	925	825
Chlorobenzene	11	14	11
1,3-Dichloropropene(cis)	ND	ND	ND
1,3-Dichloropropene(trans)	ND	ND	ND
2-Chloroethylvinylether	ND	ND	ND
Ethylbenzene	517	521	478
Non-Priority Pollutants:			
Acetone	3,980	5,080	4,940
Ethanol	26,300	31,000	30,800
Isopropanol	ND	ND	ND
2-Butanone	305	390	398
Styrene	39	56	38
Xylenes	2,190	2,210	2,090
1,1,2-Trichloro-2,2,1-trifluoroethane	5,920	5,940	6,100
Cyclohexane	ND	ND	ND
C(3)-Alkylbenzenes	276	331	169
Percent Surrogate Recovery:			
Toluene-d(8)	98%	100%	97%
Detection Limit	3	3	3

ACUREX
Corporation

Energy & Environmental Division

Acurex/ES

April 16, 1984
Acurex ID#: 8402-026B
Client PO#: 307953.20
Page 1 of 2

Attention: Walt Wyss/2-2260

Subject: Analysis of Twelve Fuel Samples for Semivolatile Organics by GC/MS, received 2/22/84.

The above referenced samples were first composited to three samples as follows: 5.0 mL of each grab sample was withdrawn while being continuously stirred with a Teflon coated magnetic stirring bar and combined with the other grab samples of the composite in a 40 mL VOA vial.

Each composite sample was then thoroughly mixed and diluted 100 times with methylene chloride. Each diluted composite sample was then analyzed by GC/MS for semivolatile organics according to EPA Method 625. Results are listed in Table 1.

If you have any questions, please call.

Prepared by: ______________________
William G. Hellier
Staff Chemist

Approved by: Viorica Lopez Avila
Viorica Lopez-Avila, Ph.D.
Technical Director

WGH/VLA/ats

Table 1. Semivolatile Organic Results

Sample ID	Concentration (µg/mL)		
	902812 902813 902825 902824	902782 902783 902794 902795	902835 902842 902843 902845
Priority Pollutants			
Naphthalene	770	720	730
2-Methylnaphthalene	680	610	670
Dibutylphthalate	280	180	570
Bis(2-ethylhexyl)phthalate	--	--	250
Nonpriority Pollutants			
Butyl acetate	1,470	830	1,160
Xylenes	2,300	2,300	1,940
Hydrocarbons[1]	12,400	12,600	13,100
Ethylmethylbenzene	650	670	650
Trimethylbenzene	1,400	1,420	1,290
Ethyl-dimethyl benzene	400	400	400
Tetramethylbenzene	400	300	300
Dimethylnaphthalene	1,000	1,000	1,290
Trimethylnaphthalene	260	200	150
Detection Limit	100	100	100

---

[1] Quantitation performed only for chromatographically resolved hydrocarbons, and not for unresolved complex mixtures.

ACUREX
Corporation

Energy & Environmental Division

Acurex/ES

April 18, 1984
Acurex ID#: 8403-035
Client PO#: 307953.20
Page 1 of 3

Attention: Walt Wyss

Subject: GC/MS analysis for Semivolatile Organics
of 3 Modified Method 5 Sample Trains

The subject sample trains were analyzed for semivolatile organics in accordance with EPA Method 625 and the following:

> For each test, the volume of the individual probe/nozzle rinse and impinger rinses was measured (see Table 2) and then combined prior to extraction. The combined impinger rinses, probe/nozzle rinses and XAD resin for each test were then extracted separately. After extraction, the extracts from each test were combined and analyzed by GC/MS.

The results are listed in Table 1.

If you have any questions, please call.

Prepared by: William G. Hellier
William G. Hellier
Staff Chemist

Approved by: Viorica Lopez-Avila
Viorica Lopez-Avila, Ph.D.
Technical Director

WGH/VLA/ats

Table 1. Semivolatile Organics Results

Sample ID	902802 902804 902805 902806	902827 902828 902830 902831 902832 902833	902858 902860 902861 902862 902863 902864	902777
Test #	1	2	3	Blank
Parameter	µg	µg	µg	µg
Priority Pollutants				
Phenol	21	20	76	1
2-Nitrophenol	6	16	11	ND
Naphthalene	5	7	26	4
Dimethyl phthalate	11	43	32	ND
2,6-Dinitrotoluene	6	6	ND	ND
2-Methyl naphthalene	15	67	ND	ND
Phenanthrene	10	16	14	ND
Dibutyl phthalate	36	13	22	3
2-Chlorophenol	ND	ND	32	ND
Bis(2-ethylhexyl)phthalate	25	6	22	ND
Benzyl alcohol	ND	12	54	ND
Detection Limit	1	1	1	1
Percent Surrogate Recovery				
Decaflurobiphenyl	41	37	53	NS
2-Fluorobiphenyl	52	47	78	33

ND - Not detected
NS - Not spiked

Table 2. Rinse Volumes (mL)

Test #	Impinger Rinse	Probe & Nozzle Rinse
I	1740	170
II	3560	380
III	3270	340

LABORATORY CERTIFICATE

CURTIS & TOMPKINS, LTD.

ESTABLISHED 1878
Bulk Oil & Chemical Surveyors, Samplers & Weighers
Analytical & Consulting Chemists

SOUTHERN DIVISION
401 Canal Street
Wilmington, CA 90748
213-540-6740
TWX 910-345-6820
ANALYST WILN

290 Division Street
San Francisco, CA 94103
415-861-1863
Telex: 171042
CABLE: ANALYST SFO

FOOD TECHNOLOGISTS
ENVIRONMENTAL ANALYSTS
MEMBERS, OFFICIAL CHEMISTS
AND/OR SAMPLERS FOR GOVERNMENT
AGENCIES AND TRADE ORGANIZATIONS

Laboratory No. 84c296
Preliminary No. 7451

Reported 3/30/84
Sampled -------
Received 3/6/84
Page 1 of 3

For ACUREX CORPORATION

Report on 12 Fuel Oil
4 Filters

Mark P.O. RB59186A, Release No. 9
and as below

	Total Chlorides	Specific Gravity Hydrometer @ 22°C
902782	0.44%	0.8900
902783	0.55%	0.8900
902794	0.35%	0.8890
902795	0.57%	0.8900
902812	0.40%	0.8880
902813	0.44%	0.8880
902825	0.51%	0.8880
902834	0.37%	0.8880
902835	0.51%	0.8880
902842	0.50%	0.8870
902843	0.54%	0.8880
902845	0.37%	0.8880

Curtis & Tompkins Ltd.

SAMPLES DISCARDED 30 DAYS AFTER RECEIPT UNLESS OTHERWISE REQUESTED

This report applies only to the sample, or samples, investigated and is not necessarily indicative of the quality or condition of apparently identical or similar products. As a mutual protection to clients, the public and this Laboratory, this report is submitted and accepted for the exclusive use of the client to whom it is addressed and upon the condition that it is not to be used, in whole or in part, in any advertising or publicity matter without prior written authorization from this Laboratory.

ACUREX CORPORATION
12 Fuel Oil
4 Filters
P.O. RB59186A, Release No. 9

	Composite Sample 1 902782 902783 902794 902795	Composite Sample 2 902812 902813 902825 902834	Composite Sample 3 902835 902842 902843 902845
ULTIMATE ANALYSIS, as rec'd.			
Chlorides,%	0.60	0.64	0.74
Carbon,%	76.5	76.4	76.7
Hydrogen,%	12.7	12.6	12.7
Oxygen(by difference),%	8.05	8.22	8.49
Sulfur,%	0.35	0.35	0.35
Nitrogen,%	1.1	1.1	1.1
PROXIMATE ANALYSIS, as rec'd			
Ash,%	0.70	0.69	0.66
Moisture,%	7.50	7.05	6.95
Volatile Matter,%*	98.49	98.56	98.52
Fixed Carbon,%**	0.81	0.75	0.82
Higher Heating Value BTU per Pound	17,100	17,148	17,126
METALS BY ATOMIC ABSORPTION			
Antimony,ppm	Trace(<1)	Trace(<1)	Trace(<1)
Arsenic,ppm	N.D.(1)	N.D.(1)	N.D.(1)
Beryllium,ppm	N.D.(1)	N.D.(1)	N.D.(1)
Cadmium,ppm	1.1	1.0	1.0
Chromium,ppm	4.8	4.0	4.2
Copper,ppm	460	400	410
Lead,ppm	530	630	690
Mercury,ppm	N.D.(0.1)	N.D.(0.1)	N.D.(0.1)
Nickel,ppm	1.3	1.2	1.3
Selenium,ppm	N.D.(1.0)	N.D.(1.0)	N.D.(1.0)
Silver,ppm	N.D.(1)	N.D.(1)	N.D.(1)
Thallium,ppm	N.D.(1)	N.D.(1)	N.D.(1)
Zinc,ppm	570	580	570

*Volatile Matter by difference. Includes moisture.

**Based on CCR less Ash.

Curtis & Tompkins Ltd.

ACUREX CORPORATION
12 Fuel Oil
 4 Filters
P.O. RB59186A, Release No. 9

Page 3 of 3
84c296

	FILTER, µg/Sample			
	902778	902803	902829	902859
METALS				
Mercury	N.D.(0.1)	N.D.(0.1)	N.D.(0.1)	N.D.(0.1)
Arsenic	N.D.(0.1)	Trace(<0.1)	Trace(<0.1)	Trace(<0.1)
Antimony	N.D.(3)	N.D.(3)	N.D.(3)	N.D.(3)
Beryllium	N.D.(3)	N.D.(3)	N.D.(3)	N.D.(3)
Cadmium	N.D.(2)	N.D.(2)	N.D.(2)	N.D.(2)
Chromium	N.D.(2)	10	10	14
Copper	N.D.(3)	11	92	11
Lead	N.D.(2)	23	70	90
Nickel	N.D.(2)	12	5	8
Selenium	N.D.(2)	N.D.(2)	N.D.(2)	N.D.(2)
Silver	N.D.(3)	N.D.(3)	15	4.5
Thallium	N.D.(1)	N.D.(1)	N.D.(1)	N.D.(1)
Zinc	N.D.(4)	46	59	93

Curtis & Tompkins Ltd.

Detection limits vary with sample size and analytical conditions.

N.D. = None Detected. Detection limit is indicated in parentheses.

< = Less than. A detectable trace not accurately quantifiable below the indicated detection limit.

TABLE D-2. SAMPLE IDENTIFICATION NUMBERS -- SITE II

Sample description	Test 1	Test 2	Test 3	Test 4	Blank
Date	3-6-84	3-7-84	3-8-84	3-9-84	
Waste solvent feed:					
1 of 4	902873	902921	902960	902999	
2 of 4	902876	902926	902961	903000	
3 of 4	902879	902935	902979	903011	
4 of 4	902880	902937	902980	903032	
Scrubber influent:					
VOA grab 1 of 4	902871	902919	902958	902997	
VOA grab 2 of 4	902874	902927	902962	903001	
VOA grab 3 of 4	902877	902933	902977	903009	
VOA grab 4 of 4	902881	902941	902990	903030	
General composite	902883	902943	902992	903033	
Metals composite	902900	902945	902994	903035	
Scrubber effluent:					
VOA grab 1 of 4	902872	902920	902959	902998	
VOA grab 2 of 4	902875	902928	902963	903002	
VOA grab 3 of 4	902878	902934	902978	893010	
VOA grab 4 of 4	902882	902942	902991	903031	
General composite	902884	902944	902993	903034	
Metals composite	902901	902946	902995	903036	
Method 5:					
Probe and nozzle rinse					
Run 1	902887	902923	902970	903013	902918
Run 2	902890	902930	902975	903017/018	
Run 3	902897	902939	902987	903022	
Filter					
Run 1	902885	902925	902972	903012	902898
Run 2	902888	902932	902974	903016	
Run 2	902895	902938	902988	903021	
Impinger[a]					
Run 1	902886	902922	902971	903014	902924
Run 2	902889	902931	902976	903019	
Run 3	902896	902940	902989	903023	

(continued)

[a] Not analyzed.

TABLE D-1. (Concluded)

Sample description Date	Test 1 3-6-84	Test 2 3-7-84	Test 3 3-8-84	Test 4 3-9-84	Blank
VOST Traps:					
Run 1	902902/903	902948/949	902964/965	903003/004	903026/027
Run 2	902904/905	902952/953	902968/969	903007/008	
Run 3	902908/909	902954/955	902981/982	903024/025	
Run 4	902910/911				
Field Blank	902906/907	902950/951	902966/967	903005/006	
HCl Impingers:					
Run 1	902891	902929	902973	903015	902892
Run 2	902893	902936	902985	903020	902894
Coal Samples	901693	901694	a		

ACUREX
Corporation

Energy & Environmental Division

April 5, 1984
Acurex ID#: 8403-025
Client PC#: 307953.20
Page 1 of 2

Acurex Corporation
Environmental Sciences
555 Clyde Avenue
P.O. Box 7555
Mountain View, CA 94039

Attention: Walt Wyss

Subject: Analysis for Volatile Organics of 12 Water Samples, Received 3/12/84

The subject grab samples were first composited to three samples and then analyzed by GC/MS according to EPA Method 624. Results are listed in Table 1.

If you have any questions, please call.

Prepared by:
William G. Hellier
Staff Chemist

Approved by: Viorica Lopez Avila
Viorica Lopez-Avila, Ph.D.
Technical Director

WGH/VLA/wp

Table 1.

Sample ID Parameter/Units	Day 2 Surface Water µg/L	Day 2 Scrubber Effluent µg/L	Day 4 Scrubber Effluent µg/L
Priority Pollutants:			
Chloromethane	ND	ND	ND
Bromomethane	ND	ND	ND
Vinyl Chloride	ND	ND	ND
Chloroethane	ND	ND	ND
Dichloromethane	ND	ND	ND
1,1-Dichloroethylene	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND
Trans-1,2-Dichloroethylene	ND	ND	ND
Chloroform	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND
Dichlorobromoethane	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND
Trichloroethylene	ND	ND	ND
Chlorodibromoethane	ND	ND	ND
1,1,2-Trichloroethylene	ND	ND	ND
Benzene	ND	ND	ND
Bromoform	ND	ND	ND
Tetrachloroethylene	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND
Toluene	ND	ND	ND
Chlorobenzene	ND	ND	ND
1,3-Dichloropropene(cis)	ND	ND	ND
1,3-Dichloropropene(trans)	ND	ND	ND
2-Chloroethylvinylether	ND	ND	ND
Ethylbenzene	ND	ND	ND
Detection Limit	1	1	1
Percent Surrogate Recovery:			
d8-Toluene	94	92	92
d4-1,2-Dichloroethane	110	100	110
Bromofluorobenzene	92	93	104

ACUREX
Corporation

Energy & Environmental Division

Acurex/ES

April 17, 1984
Acurex ID#: 8403-018
Client PO#: 307953.20
Page 1 of 6

Attention: Walt Wyss/2-2260

Subject: GC/MS Analysis of 18 Pairs of Tenax Traps, Received 3/12/84.

The above referenced samples were analyzed by GC/MS for volatile priority pollutants according to the EPA VOST Protocol. Additionally, the traps were analyzed for styrene, xylenes, C_3-alkyl benzenes, 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), 2-Butanone (MEK), 4-methyl-2-pentanone and 2,2'-oxybispropane (di-isopropylether). Results are listed in Table 1. Purge blank data is listed in Table 2. Trap blank data and percent recovery for spiked traps are listed in Tables 3 and 4, respectively.

If you have any questions, please call.

Prepared by:______________________
William G. Hellier
Staff Chemist

Approved by: Viorica Lopez Avila
Viorica Lopez-Avila, Ph.D.
Technical Director

WGH/VLA/ats

Table 1a. VOST Results (ng/pair traps)

ID Number Test Trap Number Parameter/Units	902902, 902903[a] 1A 9, 1A ng/pair	902906, 902907 1C Field B 11, 10A ng/pair	392908, 902909[b] 1D 21, 40A ng/pair	902910, 902911 1E 53, 31A ng/pair	902948, 902949 1A 18, 60A ng/pair	902950, 902951[c] 2B Field B 19, 8A ng/pair	902952, 902953 2C 20, 13A ng/pair	902954, 902955[d] 2D 1, 15A ng/pair
Priority Pollutants:								
Chloromethane	Sample lost	266	773	1,230	3,340	64	5,660	2,400
Bromomethane		ND	33	33	686	ND	15	16
Vinyl Chloride		ND	50	61	172	ND	97	97
Chloroethane		ND	ND	ND	ND	ND	ND	ND
Dichloromethane		813	191	129	2,470	807	1,160	399
1,1-Dichloroethylene		ND	30	13	16	ND	16	16
1,1-Dichloroethane		ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethylene		ND	12	ND	6	ND	4	ND
Chloroform		ND	65	9	31	ND	6	8
1,2-Dichloroethane		ND	10	ND	ND	ND	ND	ND
1,1,1-Trichloroethane		61	42	131	41	30	93	64
Carbon Tetrachloride		ND	121	10	20	ND	13	4
Dichlorobromoethane		ND	14	ND	ND	ND	ND	ND
1,2-Dichloropropane		ND	ND	ND	ND	ND		ND
Trichloroethylene		ND	19	7	10	ND		8
Chlorodibromoethane		ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethylene		ND	ND	ND	ND	ND	ND	ND
Benzene		6	240	160	168	3	170	202
Bromoform		ND	ND	ND	ND	ND	ND	ND
Tetrachloroethylene		ND	43	21	20	ND	15	7
1,1,2,2-Tetrachloroethane		ND	ND	ND	ND	ND	ND	ND
Toluene		7	111	108	155	6	100	140
Chlorobenzene		ND	79	82	108	ND	94	98
Ethylbenzene		3	12	11	20	ND	9	14
1,3-Dichloropropene (cis)		ND	ND	ND	ND	ND	ND	ND
1,3-Dichloropropene (trans)		ND	ND	ND	ND	ND	ND	ND
Non-Priority Pollutants:								
Styrene		ND	34	22	10	ND	43	25
Xylenes		7	44	38	37	ND	36	55
1,1,2-Trichloro-2,2,1-trifluoroethane		ND	5	3	7	ND	4	4
C_3-Alkylbenzenes		ND	11	8	9	ND	6	11
2-Butanone		ND	ND	ND	ND	ND	ND	ND
4-Methyl-2-pentanone Di-isopropylether		ND	ND	ND	70	ND	46	7
Percent Surrogate Recovery:								
d8-Toluene		65	103	88	92	84	104	103
Detection Limit		2	2	2	2	2	2	2

[a] Transport tube for trap no. 9 received hroken. Trap no. 9 received broken at stem and subsequently transferred. Trap no. 1A received with badly cracked stem. Trap no 1A broke off at neck during desorption and sample was lost.

[b] Sample extremely wet

[c] Trap no. 8A improperly capped

[d] Transport tube for trap no. 1 broken; trap no. 1 broken off at nut; sample extremely wet.

ND -- Not detected

Table 1b. VOST Results (ng/pair traps)

ID Number Test Trap Number Parameter/Units	902964, 902965 3A 4, 11A ng/pair	902966, 902967[e] 3B Field B 50, 5A ng/pair	902968, 902969 3C 16, 35A ng/pair	902981, 902982 3D 25, 30A ng/pair	903003, 903004 4A 12, 12A ng/pair	903005, 903006 4B Field B 23, 17A ng/pair	903007, 903008 4C 2, 33A ng/pair	903024, 903025 4D 58, 24A ng/pair	903026, 903027[f] 4E, Trip B 30, 20A ng/pair	Lab Blank
Priority Pollutants:										
Chloromethane	6,220	156	3,070	2,890	6,570	130	7,470	5,240	83	186
Bromomethane	87	ND	31	50	52	ND	46	58	ND	ND
Vinyl Chloride	97	ND	82	93	88	ND	76	81	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromethane	866	204	213	254	290	115	2,930	830	5,580	118
1,1-Dichloroethylene	21	6	18	15	26	ND	19	21	ND	4
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethylene	8	ND	7	5	6	ND	7	8	ND	ND
Chloroform	78	ND	12	9	34	ND	13	76	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	93	61	90	68	321	287	145	77	126	118
Carbon Tetrachloride	8	ND	17	9	18	ND	19	10	ND	ND
Dichlorobromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethylene	12	ND	10	9	10	ND	14	10	ND	ND
Chlorodibromoethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	298	5	200	231	241	9	298	170	10	5
Bromoform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethylene	14	ND	11	10	12	ND	9	10	ND	ND
1,1,2,2-Tetrachloroethane	ND	8	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	1,520	4	184	175	219	7	191	1,560	9	12
Chlorobenzene	195	ND	134	108	157	ND	128	101	ND	ND
Ethylbenzene	212	2	19	18	21	2	22	285	7	7
1,3-Dichloropropene (cis)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-Dichloropropene (trans)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Non-Priority Pollutants:										
Styrene	96	ND	52	49	40	ND	48	77	ND	6
Xylenes	593	ND	69	63	86	11	84	789	14	12
1,1,2-Trichloro-2,2,1-trifluoroethane	3	2	3	3	16	3	8	14	ND	ND
C_3-Alkylbenzenes	19	ND	12	9	25	ND	17	16	ND	ND
2-Butanone	838	ND	ND	131	96	ND	56	975	ND	ND
4-Methyl-2-pentanone	17	ND	ND	ND	13	ND	14	11	ND	ND
Di-isopropylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Percent Surrogate Recovery:										
d8-Toluene	123	108	98	109	113	87	101	118	86	86
Detection Limit	2	2	2	2	2	2	2	2	2	

[e] Stem on trap no. 50 badly cracked
[f] Transport tube for trap no. 20A loosely capped, trap badly cracked.

Table 2. Purge Blanks (ng/pair traps) —

Date Parameter/Units	3/16/84 ng/pair	3/16/84 ng/pair	3/20/84 ng/pair	3/20/84 ng/pair	3/21/84 ng/pair	3/21/84 ng/pair
Priority Pollutants:						
Chloromethane	ND	ND	9	ND	ND	5
Bromomethane	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND
Dichloromethane	73	55	48	42	37	60
1,1-Dichloroethylene	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND
Trans-1,2-Dichloroethylene	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND
Dichlorobromoethane	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND
Trichloroethylene	ND	ND	ND	ND	ND	ND
Chlorodibromoethane	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethylene	ND	ND	ND	ND	ND	ND
Benzene	2	5	2	2	1	1
Bromoform	ND	ND	ND	ND	ND	ND
Tetrachloroethylene	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND
Toluene	10	9	3	4	1	3
Chlorobenzene	ND	ND	ND	ND	ND	ND
Ethylbenzene	9	9	ND	ND	ND	3
1,3-Dichloropropene (cis)	ND	ND	ND	ND	ND	ND
1,3-Dichloropropene (trans)	ND	ND	ND	ND	ND	ND
Non-Priority Pollutants:						
Styrene	2	12	ND	2	ND	3
Xylenes	17	16	2	2	ND	3
1,1,2-Trichloro-2,2,1-trifluoroethane	3	ND	2	1	ND	ND
C_3-Alkylbenzenes	ND	ND	ND	ND	ND	ND
2-Butanone	ND	ND	ND	ND	ND	ND
4-Methyl-2-pentanone	ND	ND	ND	ND	ND	ND
Di-isopropylether	ND	ND	ND	ND	ND	ND
Percent Surrogate Recovery:						
d8-Toluene	88	102	100	119	109	104
Detection Limit	2	2	2	2	2	2

Table 3. Trap Blanks (ng/pair traps)

Date Parameter/Units	3/16/84 ng/pair	3/20/84 ng/pair	3/21/84 ng/pair
Priority Pollutants:			
Chloromethane	132	146	184
Bromomethane	ND	ND	ND
Vinyl Chloride	ND	ND	ND
Chloroethane	ND	ND	ND
Dichloromethane	70	56	97
1,1-Dichloroethylene	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND
Trans-1,2-Dichloroethylene	ND	ND	ND
Chloroform	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND
Dichlorobromoethane	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND
Trichloroethylene	ND	ND	ND
Chlorodibromoethane	ND	ND	ND
1,1,2-Trichloroethylene	ND	ND	ND
Benzene	6	7	5
Bromoform	ND	ND	ND
Tetrachloroethylene	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND
Toluene	10	3	4
Chlorobenzene	ND	ND	ND
Ethylbenzene	5	1	ND
1,3-Dichloropropene (cis)	ND	ND	ND
1,3-Dichloropropene (trans)	ND	ND	ND
Non-Priority Pollutants:			
Styrene	2	ND	ND
Xylenes	13	ND	ND
1,1,2-Trichloro-2,2,1-trifluoroethane	ND	1	21
C_3-Alkylbenzenes	ND	ND	ND
2-Butanone	ND	ND	ND
4-Methyl-2-pentanone	ND	ND	ND
Percent Surrogate Recovery:			
d8-Toluene	88	88	114

Table 4. Trap Spike Recovery

Date Parameter/Units	3/16/84 % Recovery	3/20/84 % Recovery	3/21/84 % Recovery
Priority Pollutants:			
Chloromethane	172	253	250
Bromomethane	115	95	96
Vinyl Chloride	103	105	94
Chloroethane	93	214	101
Dichloromethane	118	110	117
1,1-Dichloroethylene	139	120	99
1,1-Dichloroethane	123	110	103
Trans-1,2-Dichloroethylene	144	75	99
Chloroform	148	58	97
1,2-Dichloroethane	105	75	78
1,1,1-Trichloroethane	135	70	100
Carbon Tetrachloride	150	74	100
Dichlorobromoethane	125	45	89
1,2-Dichloropropane	96	50	82
Trichloroethylene	101	79	51
Chlorodibromoethane	76	28	39
1,1,2-Trichloroethylene	66	42	65
Benzene	90	78	86
Bromoform	80	32	56
Tetrachloroethylene	142	72	71
1,1,2,2-Tetrachloroethane	68	71	74
Toluene	115	75	74
Chlorobenzene	122	62	68
Ethylbenzene	135	62	81
1,3-Dichloropropene (cis)	77	50	79
1,3-Dichloropropene (trans)	73	48	75
Non-Priority Pollutants:			
Styrene	117	53	62
Xylenes	134	56	72
1,1,2-Trichloro-2,2,1-trifluoroethane	151	75	114
C_3-Alkylbenzenes	NS	NS	NS
2-Butanone	127	54	122
4-Methyl-2-pentanone	52	27	28
Percent Surrogate Recovery:			
d8-Toluene	86	92	92

NS - Not spiked

ACUREX
Corporation

Energy & Environmental Division

Acurex/ES
MS 2-2260

April 17, 1984
Acurex ID#: 8403-024
Client PO#: 307953.20
Page 1 of 2

Attention: Walt Wyss

Subject: Eight Samples for Chloride Content and Four Samples for Priority Pollutants Metals, Received 3/12/84

The above samples were analyzed for chloride and total nitric acid recoverable metals following "Standard Methods for the Examination of Water and Wastewater, 15th edition". Results are presented in Tables 1 and 2.

Prepared by:

John S. Labash

John S. Labash
Chemist

Approved by:

Greg Nicoll

Greg Nicoll
Manager, Inorganic Chemistry

Table 1. Chloride Determinations

Sample ID	Volume, mL ± 5 mL	Concentration, mg/L
902900	935	6
902901	920	540
902945	1,000	5
902946	985	400
902992	915	6
902993	995	610
903035	935	6
903036	935	650
Detection Limit	--	2

Table 2. Metals Concentration, mg/L

Sample ID	902943	902944	903033	903034	Laboratory Blank	Detection Limit
Antimony	ND	0.05	ND	0.08	ND	0.01
Arsenic	ND	0.63	ND	0.71	ND	0.02
Beryllium	ND	ND	ND	ND	ND	0.01
Cadmium	ND	0.13	ND	0.16	ND	0.01
Chromium	ND	0.93	ND	1.3	ND	0.02
Copper	ND	1.2	ND	1.5	ND	0.02
Lead	ND	9.5	ND	11	ND	0.04
Mercury	ND	ND	ND	ND	ND	0.001
Nickel	ND	0.16	ND	0.23	ND	0.02
Selenium	ND	ND	ND	ND	ND	0.03
Silver	ND	ND	ND	ND	ND	0.02
Thallium	ND	ND	ND	ND	ND	0.01
Zinc	ND	2.0	ND	2.8	ND	0.02

LABORATORY CERTIFICATE

CURTIS & TOMPKINS, LTD.

ESTABLISHED 1878

Bulk Oil & Chemical Surveyors, Samplers & Weighers
Analytical & Consulting Chemists

SOUTHERN DIVISION
401 Canal Street
Wilmington, CA 90748
213-549-6740
TWX 910-345-6820
ANALYST WILN

290 Division Street
San Francisco, CA 94103
415-861-1863
Telex: 171042
CABLE: ANALYST SFO

FOOD TECHNOLOGISTS
ENVIRONMENTAL ANALYSTS
MEMBERS, OFFICIAL CHEMISTS
AND/OR SAMPLERS FOR GOVERNMENT
AGENCIES AND TRADE ORGANIZATIONS

Laboratory No. 84d143
Preliminary No. 4588

Reported 4/18/84
Sampled -------
Received 3/23/84

Page 1 of 3

For ACUREX CORPORATION

Report on 24 samples of Products

Mark Contract No: RB59186A
Release #12

	Specific Gravity $\frac{20°C}{20°C}$	Total Chlorides ,%
902868	0.8822	2.13
902870	0.8975	1.10
902873	0.9019	2.02
902876	0.8998	1.40
902879	0.9021	1.95
902880	0.9179	1.30
902921	0.8981	2.12
902926	0.8972	2.10
902935	0.8966	2.10
902937	0.8987	1.85
902960	0.8799	2.32
902961	0.8853	2.30
902979	0.8890	2.25
902980	0.8882	2.20
902999	0.8928	2.12
903000	0.8898	2.20
903011	0.8725	2.56
903032	0.8742	2.50

Curtis & Tompkins Ltd.

SAMPLES DISCARDED 30 DAYS AFTER RECEIPT UNLESS OTHERWISE REQUESTED

This report applies only to the sample, or samples, investigated and is not necessarily indicative of the quality or condition of apparently identical or similar products. As a mutual protection to clients, the public and this Laboratory, this report is submitted and accepted for the exclusive use of the client to whom it is addressed and upon the condition that it is not to be used, in whole or in part, in any advertising or publicity matter without prior written authorization from this Laboratory.

ACUREX CORPORATION
RB59186A Release 12
84d143

CURTIS & TOMPKINS, LTD.
4/18/84
Page 2 of 3

	Composite No. 1	Composite No. 2	Composite No. 3	Composite No. 4
	902870 902873 902876 902879 902880	902921 902926 902935 902937	902960 902961 902979 902980	902999 903000 903011 903032
ULTIMATE ANALYSIS				
Carbon,% ----------	52.0	55.2	61.9	62.0
Hydrogen,% --------	10.5	11.0	10.6	10.5
Oxygen(by Difference),%	33.5	29.8	24.4	24.5
Sulfur,% ----------	0.18	0.20	0.22	0.17
Nitrogen,% --------	0.7	0.8	0.3	0.3
PROXIMATE ANALYSIS				
Ash,% -------------	3.09	2.98	2.54	2.53
Moisture,% --------	20.29	18.26	13.38	12.34
Volatile Matter,% --	75.30	77.77	83.26	84.24
Fixed Carbon,% ----	1.32	0.99	0.82	0.89
Higher Heating Value BTU per LB ------	11,696	12,208	13,102	13,368
METALS ATOMIC ABSORPTION				
Antimony , ppm ------	9.4	9.0	8.0	9.4
Arsenic , ppm -------	ND(1)	ND(1)	ND(1)	ND(1)
Beryllium , ppm -----	ND(0.1)	ND(0.1)	ND(0.1)	ND(0.1)
Cadmium , ppm -------	8.5	8.9	8.9	9.6
Chromium , ppm ------	140	130	105	130
Copper , ppm --------	92	90	92	105
Lead , ppm ----------	750	975	900	950
Mercury , ppm -------	0.5	0.6	0.4	0.6
Nickel , ppm --------	2.9	2.7	2.7	2.9
Selenium , ppm ------	ND(1)	ND(1)	ND(1)	ND(1)
Silver , ppm --------	Trace(<0.5)	Trace(<0.5)	Trace(<0.5)	Trace(<0.5)
Thallium , ppm ------	Trace(<1)	Trace(<1)	Trace(<1)	Trace(<1)
Zinc , ppm ----------	175	250	260	310

Detection limits vary with sample size and analytical conditions.
ND = Not Detected. Detection limit is indicated in parentheses.
< = Less than. A detectable trace not accurately quantifiable below the indicated detection limit.

ACUREX CORPORATION
RB59186A Release 12

4/18/84

	902898	902895	902932	902974	903016
POLLUTANT METALS, Total µg					
Mercury	ND(0.2)	ND(0.2)	ND(0.2)	ND(0.2)	ND(0.2)
Arsenic	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Antimony	ND(2)	ND(2)	ND(2)	ND(2)	ND(2)
Beryllium	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Cadmium	ND(1)	65	35	160	150
Chromium	ND(50)	650	450	500	400
Copper	ND(5)	160	90	400	350
Lead	ND(10)	3,300	2,200	8,900	8,500
Nickel	ND(5)	70	ND(5)	ND(5)	ND(5)
Selenium	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Silver	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Thillium	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Zinc	86	490	240	1,530	1,560

Detection limits vary with sample size and analytical conditions.
ND = Not Detected. Detection limit is indicated in parentheses.
< = Less than. A detectable trace not accurately quantifiable below the indicated detection limit.

ACUREX Corporation

Energy & Environmental Division

May 22, 1984
Acurex ID #: 8403-019
Client PO #: 307953.20
Page 1 of 3

Attention: Walt Wyss

Subject: Analysis of 17 Fuel (Solvent) Samples for Volatile and Semivolatile Organics by GC/MS, Received 3/14/84

The referenced samples were composited to four samples, as follows: 5.0 mL of each grab sample was withdrawn while the sample was continuously stirred with a Teflon-coated magnetic stirring bar and combined with the other subsamples in a 40-mL VOA vial.

The composite samples were diluted 1:100 in methanol. 100 ul of the diluted samples were added to 5.0 ml of HPLC water and analyzed for volatile organics by the purge and trap technique according to EPA Method 624. The following nonpriority pollutant compounds were identified: acetone, ethanol, isopropanol, methyl acetate, tetrahydrofuran, diethyl ether, 1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113), 2-Butanone (MEK), ethyl acetate, n-Butanol, 1-Chlorobutane, 1-Methyl ethyl acetate, 2,2'-Oxybis propane (Di-isopropyl ether), 4-Methyl-2-pentanone (MIBK), hexylacetate, xylenes, Styrene, dichlorobenzenes, C_3-alkyl benzenes, C_4-alkyl benzenes, and C_6 through C_9 normal, branched, and cyclized alkanes. The priority pollutants and the ten nonpriority pollutants to be quantitated are listed in table 1.

The composite samples were analyzed for semivolatile organics using a 1:100 dilution of the sample in methylene chloride and analyzing by GC/MS in accordance with EPA Method 625.1. The semivolatile analysis results are listed in table 2. Only eight compound groups (alkyl benzenes) plus total hydrocarbons are reported because, except for a few priority pollutants, they were the major constituents of the samples.

If you have any questions, please call.

Prepared by: William G. Hellier
Staff Chemist

Approved by: Viorica Lopez-Avila, Ph.D.
Technical Director

WGH/VLA/wp

Table 1. Volatile Organic, µg/ml

Composites		902870 902873 902876 902879	902921 902926 902935 902937	902960 902961 902979 902980	902999 903000 903011 903032
Day	Method Blank	1	2	3	4
Chloroethane	ND	2,500	2,900	3,350	3,500
Dichloromethane	130	3,990	4,280	4,960	4,920
1,2-Dichloroethane	ND	117	117	130	140
1,1,1-Trichloroethane	ND	1,450	1,630	2,010	2,030
Carbon tetrachloride	ND	59	65	83	82
1,2-Dichloropropane	ND	10	12	8	13
Trichloroethylene	ND	543	636	442	732
Benzene	3	94	111	78	131
Tetrachloroethylene	ND	2,450	2,940	2,110	3,530
Toluene	ND	36,800	37,800	26,600	43,700
Chlorobenzene	ND	147	148	119	184
Ethylbenzene	ND	16,600	19,600	14,900	24,000
Styrene	ND	1,110	1,250	830	1,400
Xylenes	24	64,600	69,700	51,700	84,100
1,2-Trichlor-2,2-trifluorethane	ND	5,860	7,630	8,900	8,980
C_3-alkylbenzenes	ND	1,690	1,850	1,350	2,260
2-butanone (MEK)	ND	11,400	15,800	13,200	14,100
4-Methyl-2-pentanone	ND	9,120	12,300	7,380	12,300
Di-Isopropyl ether	ND	>4,600	>4,600	>4,600	>4,600
Detection limits (µg/ml)	2	2	2	2	2
Percent surrogate recovery d_8-toluene	94	128	125	126	124

ND = Not detected

Table 2. Results of Semivolatile Analysis, µg/ml

Composites	902870 902873 902876 902879 902880	902921 902926 902935 902937	902960 902961 902979 902980	902999 903000 903011 903032
Day	1	2	3	4
Priority Pollutants				
Phenol	2,900	2,750	2,790	2,530
1,3-Dichlorobenzene	180	195	230	220
1,4-Dichlorobenzene	1,360	1,460	1,680	1,630
1,2-Dichlorobenzene	5,420	5,880	6,330	6,200
2,4-Dimethylphenol	780	770	1,020	910
Naphthalene	1,040	1,170	1,310	1,350
4-Methylphenol	1,160	1,140	1,210	1,050
2-Methylphenol	620	620	680	610
2-Methylnaphthalene	100	100	130	130
Nonpriority Pollutants[a]				
Xylene (three isomers)	18,000	18,000	18,000	25,700
Ethylmethylbenzene	1,500	1,500	2,000	2,000
Trimethybenzene	3,000	3,000	3,000	2,600
Methylpropylbenzene	800	1,000	900	900
Tetramethylbenzene	1,800	1,800	1,800	1,800
Hydrocarbons[b]	7,000	7,500	8,200	8,000
Propylbenzene	750	1,000	1,000	900
Diethylbenzene	500	500	500	500
Detection limits (µg/ml)	100	100	100	100

[a] Quantitation of nonpriority pollutants is based on peak height relative to nearest internal standard

[b] The concentration of hydrocarbons was estimated by summing the height of peaks m/e = 57 (characteristic of hydrocarbons) and ratioing this to the height of the internal standard naphthalene-d_8

LABORATORY CERTIFICATE

CURTIS & TOMPKINS, LTD.
ESTABLISHED 1878
Bulk Oil & Chemical Surveyors, Samplers & Weighers
Analytical & Consulting Chemists

FOOD TECHNOLOGISTS
ENVIRONMENTAL ANALYSTS
MEMBERS, OFFICIAL CHEMISTS
AND/OR SAMPLERS FOR GOVERNMENT
AGENCIES AND TRADE ORGANIZATIONS

SOUTHERN DIVISION
401 Canal Street
Wilmington, CA 90744-6503
213-540-6740

290 Division Street
San Francisco, CA 94103-4882
415-861-1863
Telex: 171042
CABLE: ANALYST SFO

Laboratory No.	84g47
Preliminary No.	8126
Reported	7/6/84
Sampled	--------
Received	6/20/84

For ACUREX CORPORATION

Report on 2 samples of Coal

Mark
1) 901693, 3/6/84 10:45 am from #5 coal feeder
2) 901694, 3/7/84 2:45 pm from #5 coal feeder

Subcontract RB59186A
Release No. 17

	1	2
ULTIMATE ANALYSIS (Dry Basis)		
Carbon, %	77.1	76.9
Oxygen (by difference), %	9.1	10.3
Hydrogen, %	5.2	5.1
Sulfur, %	0.70	1.30
Nitrogen, %	0.8	0.9
PROXIMATE ANALYSIS (Dry Basis)		
Moisture (as Received), %	1.55	1.45
Ash, %	7.05	5.46
Higher Heating Value, BTU per lb.	13,960	14,209
Fixed Carbon, %	59.01	57.30
Volatile Matter, %	33.94	37.24
Lead, ppm	14	15
Zinc, ppm	25	6
Cadmium, ppm	ND(1)	ND(1)
Chromium, ppm	Trace(<5)	Trace(<5)
Nickel, ppm	9	5
Copper, ppm	10	15

Curtis & Tompkins Ltd.

SAMPLES DISCARDED 30 DAYS AFTER RECEIPT UNLESS OTHERWISE REQUESTED

This report applies only to the sample, or samples, investigated and is not necessarily indicative of the quality or condition of apparently identical or similar products. As a mutual protection to clients, the public and this Laboratory, this report is submitted and accepted for the exclusive use of the client to whom it is addressed and upon the condition that it is not to be used, in whole or in part, in any advertising or publicity matter without prior written authorization from this Laboratory.

d